REPORT RESUMES

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EARTH SCIENCE, A GUIDE FOR TEACHERS.

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THE METHODS, MATERIALS, AND CONTENT FOR A RECOMMENDED EIGHTH GRADE SCIENCE COURSE ARE DESCRIBED. INTRODUCTORY REMARKS INCLUDE DISCUSSIONS OF RECENT TRENDS IN SCIENCE EDUCATION, THE RATIONALE FOR AN EARTH SCIENCE COURSE, AND QUALIFICATIONS NECESSARY FOR TEACHING THE COURSE. THE EARTH SCIENCE COURSE CONTENT IS DIVIDED INTO SEVEN UNITS. THE FOLLOWING KINDS OF INFORMATION ARE SUPPLIED FOR EACH UNIT--(1) RATIONALE, (2) PRINCIPLES INVOLVED, (3) EQUIPMENT REQUIRED, (4) PROCEDURES TO BE EMPLOYED, (5) POSSIBLE OUTCOMES, (6) CONTINUING ACTIVITIES, (7) FUNDAMENTAL CONCEPTS, (8) LISTS OF FILMS, MAPS, FILMSTRIPS, AND CHARTS, (9) STUDENT REFERENCES, AND (10) TEACHER REFERENCES. (RS)

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EARTH SCIENCE

A Guide For Teachers

MDCCCXX

HUBERT WHEELER
Commissioner of Education

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EXECUTIVE COMMITTEE

HUBERT WHEELER, Commissioner of Education, State Department of Education,

P.J. NEWELL, JR., Assistant Commissioner of Education, State Department of Education

RAYMOND A. ROBERTS, Director of Curriculum, State Department of Education,

STATEWIDE EARTH SCIENCE CURRICULUM COMMITTEE

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MR. CHARLES CAMPBELL, Science Supervisor, Columbia Public School, Columbia; **Chairman**

MRS. MARJORIE ELLIOTT, Earth Science Instructor, Southwest High School, Kansas City; **Secretary**

DR. VICTOR ALLEN, Director of Geology & Geological Engineering, St. Louis University, St. Louis

MR. GERALD BAYSINGER, Earth Science Instructor, Westport High School, Kansas City

MR. HAROLD A. BOEKENHEIDE, Earth Science Instructor, Affton School District, St. Louis

MR. DOMENIC COLOMBATTO, JR., Earth Science Instructor, Raytown Public Schools, Raytown

MISS JENNIVIEVE HERMAN, Earth Science Instructor, Maplewood-Richmond Heights High School, Maplewood

DR. W.D. JOHNS, Professor of Geology, Washington University, St. Louis

MR. EDGAR PHILLIPS, Earth Science Instructor, Palmer Junior High School, Independence

DR. PAUL PROCTOR, Dean of School of Science & Professor of Geology, Rolla School of Mines, Rolla

DR. A.G. UNKLESBAY, Professor of Geology and Chairman of Department of Geology, University of Missouri, Columbia

BIOGRAPHIC INFORMATION

STATEWIDE EARTH SCIENCE COMMITTEE

CHARLES C. CAMPBELL, Science Supervisor, Columbia Public Schools; EDUCATION: B.S., and M.A., University of Missouri; Earth Science Institute, University of Missouri; Special Research University of California auspices of American Academy of Arts and Sciences; post graduate courses University of Missouri; EXPERIENCE: Five years, high school science teacher, Hickman High School, Columbia, Missouri; science supervisor grades 1-12; adult education teacher; laboratory assistant and supervisor NSF Biology Institute, University of Missouri; 1966 Administrative Assistant to Superintendent, Columbia Public Schools; PROFESSIONAL ORGANIZATIONS: Sigma Xi; Research Society for Scientists; Phi Delta Kappa Educational Honorary Society; Pi Etta Sigma undergraduate science honorary; Gamma Alpha, graduate science honorary; member of local, state, and national professional organizations; Director of Prairie Foundation of Missouri; PUBLICATIONS: National journals.

MARJORIE ELLIOTT, Science Teacher, Kansas City Public Schools; EDUCATION: B.S. in Education, University of Missouri, Columbia; M.A., University of Missouri at Kansas City, 1952; University of Wisconsin and Colorado State at Greeley, and University of Kansas; EXPERIENCE: Thirty years in Kansas City, 21 at junior and senior high level, ten years in science; six year freshman English at Kansas City Junior College; one year geology at Kansas City Art Institute; PROFESSIONAL ORGANIZATIONS: National Science Teachers Association; MSTA; Kansas City Science Teachers Association, Vice-President, 1964, President 1965; Missouri Science Teachers Association; Association of High School Women; Delegate from Kansas City to National Science Teacher's annual convention, Denver; Delegate from Kansas City Science Teachers to MSTA St. Louis; PUBLICATIONS: Paper for National Council of Geographic Education, Annual meeting in New York, 1965 – **World Water Resources and Problems.**

Dr. VICTOR T. ALLEN, Proffessor of Geology and Director Geological Engineering, St. Louis University; EDUCATION: A.B., University of Minnesota; M.S., University of Minnesota, Ph.D., University of California; Assistant Geology Department, University of Minnesota; Instructor in Geology Western Reserve University; Instructor Geological Sciences, University of California; Assistant Professor Geology St. Louis University; Associate Professor Geology, St. Louis University; Professor Geology St. Louis University; Director of Geology and Geological Eng., St. Louis University; EXPERIENCE: Minnesota Geological Survey (summers); Illinois State Geological Survey (summers); Missouri Geological Survey (summers); U.S. Geological Survey (commodity geologist); U.S., Geology Survey (Senior Geologist, WAE); PROFESSIONAL ORGANIZATIONS: Fellow, Geological Society of America; Fellow, Mineralogical Society of America; Fellow, American Association for Advancement of Science; Fellow, Geological Society of Washington; Fellow, International Institute of Arts and Letters; Member, American Association of University Professors; Member, Sigma Xi; Member, American Society of Engineering Education; PUBLICATIONS: Over 100 in number, including textbooks, professional books, bulletins, articles, and abstracts in the field of geology.

GERALD G. BAYSINGER, Science Teacher, Westport High School, Kansas City, Missouri; EDUCATION: B.A., Geology and Geography, UMKC, 1954; M.A. Ed. Adm. and Supervision, UMKC, 1959; EXPERIENCE: Teacher of earth science and general science, ten years; N.S.F. Summer Institute – Physics, Chemistry, Biology, William Jewel College, 1960; N.S.F. Summer Institute Geology, University of Missouri 1966; PROFESSIONAL ORGANIZATIONS: Member Kansas City Science Teachers Association.

HAROLD A. BOEKENHEIDE, Science Teacher Affton Senior High School; EDUCATION: A.B., Missouri Valley College; M.S., University of Wyoming; Graduate Work, University of Missouri, Washington University and Hope College; EXPERIENCE: Affton Senior High School, 27 years; PROFESSIONAL ORGANIZATIONS: National Education Association; National Science Teachers Association; American Chemical Society, Educational Division; Phi Delta Kappa; MSTA; St. Louis Suburban Teachers Association.

DOMENIC COLOMBATTO, JR., Science Teacher, Raytown Public Schools; EDUCATION: B.S., M.S., and Education Specialist Degrees Central Missouri State College; EXPERIENCE: 17 years in public junior and senior high schools in Missouri; taught classes for Central Missouri State College at Residence Center in Independence, Missouri; PROFESSIONAL ORGANIZATIONS: Life member of the National Education Association; life member of National Science Teachers Association; life member of the Phi Delta Kappa; member of MSTA; member of Raytown Community Teachers Association; Vice-President, Delta Rho Campus Chapter of Phi Delta Kappa; President of Central Missouri State College Alumni Association; Delegate to Missouri State Teachers Association; National Science Teachers Association.

JENNIVIEVE LILLIAN HERMAN, Science Teacher, Maplewood-Richmond Heights Public Schools; EDUCATION: A.B., and M.A., from Kansas University 1928, 1929, graduate classes Washington University, St. Louis; EXPERIENCE: two years Garden City Kansas grade school; one year Lane Co. Kansas rural school; one year University of Kansas, Assistant Instructor Zoology; Maplewood-Richmond Heights High School, general science, biology, earth science 37 years; PROFESSIONAL ORGANIZATIONS: NEA; MSTA; SLSTA; CTA of Maplewood-Richmond Heights Group Health Association of St. Louis (Member of Board of Directors – 20 years).

DR. W.D. JOHNS, Professor and Chairman Department of Earth Science; EDUCATION: B.A., College of Wooster; M.A., and Ph.D., University of Illinois; EXPERIENCE: Research Assistant Eng. Exp. Sta., University of Illinois; Research Association Department Geology, University of Illinois; Assistant Professor Geology, University of Illinois; Assistant Professor Geology, Washington University; Professor Geology Washington University; Acting Chairman, Washington University; Chairman Department of Earth Sciences, Washington University; PROFESSIONAL ORGANIZATIONS: Fellow Geological Society America; Geo-chemical Society; American Mineralogical Society; Mineralogical Society of Great Britain and Ireland; Canadian Mineralogical Society; Deutsche Mineralogische Gesellschaft; Clay Mineral Society; Sigma XI; Phi Beta Kappa; SPECIAL ACADEMIC ACTIVITIES: Senior Fulbright Research Scholar, Mineral Institute, University of Goettingen, Germany; Interfoundational Grant, U.S., Education Committee, Hebrew University, Jerusalem; Lecture Series sponsored by Committee for Educational Exchange between U.S. and Spain; Participant, International Symposium on Marine Geochemistry, Dusseldorf, Germany; PUBLICATIONS: Author of three and coauthor of fifteen publications.

EDGAR A. PHILLIPS, Science Teacher, Independence Public Schools; EDUCATION: B.S., University of Missouri, 1959, Master Natural Science, University of Oklahoma, 1965; EXPERIENCE: Seven years teaching general science, Independence Missouri Public schools; In-Service-Institute, William Jewell College; Summer Institute Baylor University; Summer Sequential Institute University of Oklahoma; PROFESSIONAL ORGANIZATIONS: Independence Community Teachers Association; MSTA; NEA.

DR. PAUL DEAN PROCTOR, Dean of School of Science, Professor of Geology, University of Missouri at Rolla; EDUCATION: B.A., University of Utah; M.A., Cornell University; Ph.D., Indiana University; EXPERIENCE: Professor and Chairman Department of Geology, University of Missouri at Rolla; Associate Professor of Geology, Indiana University; Brigham Young University; Geologist, U.S. Geological Survey 1943-53; Exploration geologist, 1953-57; International Geological Congresses, Mexico 1956, Denmark, 1960; International Field Institute, Italy, 1964; PROFESSIONAL ORGANIZATIONS: Fellow GSA; Member AIME; SEG; Sigma Xi; Phi Kappa Phi; Gamma Alpha; AMG; AAAS; MAS; UGS; PUBLICATIONS: Scientific articles and one book.

DR. A.G. UNKLESBAY, Chairman Geology Department, University of Missouri; EDUCATION: A.B., Marietta College, 1938; M.A., University of Iowa 1940; Ph.D., 1942; EXPERIENCE: U.S. Geological Survey 1942-45, Alaska-Strategic minerals, Florida and Puerto Rico Ground-Water supplies; Iowa Geological Survey, 1945-46, Water supply and mineral resources; Colgate University, 1946-47, Institute of Geology; University of Missouri 1947-Present, Assistant Professor, Associate Professor, Professor of Geology. At present, Professor of Geology and Chairman of Department; PROFESSIONAL ORGANIZATIONS: American Association of Petroleum Geologists; Fellow Geological Society of America; Paleontological Society; Society of Economic Paleontologists and Mineralogists; Association of Missouri Geologists; National Association of Geology Teachers; Missouri Academy of Science; PUBLICATIONS: **Geology of Boone County, Missouri,** Geological Survey Bulletin Vol. 33, 1952; **Common Fossils of Missouri,** University of Missouri Handbook No. 4, 1955; Penn. Cephalopods of Oklahoma, Oklahoma Geology Survey Bulletin 96, 1962; 25 Journal articles in Paleontology and in Geology of Ground Water.

FOREWORD

This guide represents a "first" for Missouri. Heretofore, earth science has been taught in correlation with general science. It is apparent that the recent exploration of space has caused a renewed interest in the physical properties and processes of the planet earth notably, because it serves as a source for comparison and speculation.

Recent emphasis on earth science at the national level and current interest of educators at the state level indicate that a separate course in earth science is needed and would be acceptable. Therefore, a statewide committee was appointed in September, 1964, to study and develop a curricular guide in this interdiscipline. A review of the content of this publication reveals that the structure and organization is not only in accordance with recent theoretical developments in science education but, also practical and functional in application as a pre-training medium and as a guide for implementing the course at the classroom level.

I commend the Committee for excellent work in developing this curricular innovation for use in Missouri schools. It is apparent that the knowledge of the specialists in earth science and the experience of successful classroom teachers have been fused in the development of this guide. The Committee's untiring interest and special knowledge applied to this task is appreciated.

Hubert Wheeler

State Commissioner of Education

OVERALL POINT of VIEW

OVERALL POINT OF VIEW

INTRODUCTION

The current revision of the science curriculum has been fostered by unparalleled curricular changes, not to mention the doubling of scientific knowledge during the past decade. It is recognized by the committee responsible for developing this guide that changes will continue; therefore, this guide has been designed to encourage teacher-experimentation with the newer methods and approaches.

BASIC TRENDS IN SCIENCE EDUCATION SINCE 1960

Recent research in science education fostered by the National Science Foundation Projects, reveals the following trends and influences:

1. The trends in elementary science, grades 1-6, continue toward the introduction of basic concepts taught under the direction of a science specialist or supervisor.

2. There is a definite trend toward emphasis on laboratory work at all levels.

3. The trend toward specialized courses at the junior high level continues – life science, earth science, and physical science are becoming predominant. There is a definite trend away from general science at the secondary level.

4. The trend toward advanced courses at the twelfth grade level continues. Research seminars and independent studies are emerging as a pattern in advanced courses.

5. The trend continues from broad coverage of subject matter to carefully selected content for study in "depth".

SCIENCE IN TRANSITION

Science education in transition since 1958 represents a transitional "from-to" process described, in brief, as follows:

1. From teacher-textbook centered instruction to a conceptual approach that develops a sense of discovery by means of a series of laboratory experiments.

2. From teacher-centered laboratory demonstration approach to pupil-centered laboratory work.

3. From emphasis on rote memorization of facts and principles to emphasis on understanding through student participation in laboratory activities.

4. From a point of view that the study of science is for only a small fraction of the students, to the belief that understanding of basic principles of the biological and physical sciences is needed for all students.

Specialists in the field believe that the recent innovations in science education are far superior to the traditional course as represented by the 1950 edition of Missouri guides in science. The national programs will, no doubt, continue to influence science education at the state level. Diffusion rates of one-third and over, have been reported. There is no doubt that these programs represent the best, current thinking of leading science educators and scientists. It is reported that about sixty per cent of the science textbooks published since 1962, reflect the basic principles of these programs in a greater or lesser degree. In all cases, the orientation of the so-termed modern approaches should be toward a better understanding of the methods of investigation which implies more emphasis on pupil-participation in laboratory-centered situations with a maximum of problem-solving experiences.

ORGANIZATION

This revision is organized on the basis of the 6-6 plan of school organization rather than on the 6-3-3 basis of the 1950 edition. This change has been made to provide for a more logical continuity in scope and sequence and to avoid the inference of a "gap" between the elementary and high school courses. Grades seven through twelve are to be considered as the secondary program. This does not, however, exclude considering grades seven and eight or grades seven through nine as the junior high program.

OBJECTIVES

1. To cultivate an interest in science so that it will become a natural part of the student's life.
2. To develop skill in recognizing and stating basic problems and resolving them into component problems.
3. To develop skill in using the facilities of the science laboratory to investigate problems.
4. To develop skill in interpreting and reporting experimental investigations.
5. To develop the ability to use scientific literature as an aid in the solving of problems and for independent study.

METHODS

Combinations of methods should be used by teachers in science instruction.

Textbook-centered Method

The overuse of this method remains questionable, notably because it implies assigning of pages, hearing of lessons, memorization of facts, principles, and passing a test with little or no attention given to laboratory activities and the process of rationalization.

The Laboratory Method

The committee responsible for developing this guide strongly recommends the laboratory method as a basis for teaching science. The science programs developed by ESCP, BSCS, PSSC, CHEM, CBA, and other innovations emphasize the importance of laboratory experiences for pupils individually and collectively. In fact, initial learning is introduced through a laboratory experience in these programs.

Teachers should gradually discard the "cookbook" style of laboratory exercise and utilize the principles of self-discovery through problem-solving, and open-ended experiments.

The Demonstration Method

The demonstration method can be an effective extension of the laboratory method for collecting data and illustrating phenomena which can not be conveniently or safely handled in the laboratory by the individual student.

USE OF AUDIO-VISUAL MATERIALS

Audio-visual materials are valuable as a supplement and/or a means of initial presentation. The science programs such as BSCS, PSSC, CHEM, CBA, and ESCP have developed many excellent films.

OTHER MATERIALS

Other means and methods such as programmed texts, teaching machines, the field trip, and closed circuit television should be investigated and utilized as a means of improving science instruction.

INTERRELATEDNESS

In the final analysis, it must be recognized that psychologically, no subject is learned in isolation nor does a pupil learn one thing at a time just because a bell signals the separateness of classes. Students enrolled in a science course are scheduled in at least four other courses – mathematics, social studies, language arts, health-physical education, and in some cases, a foreign language. It is recognized that individual students tend to integrate knowledge and formulate concepts on their own, but teachers should attempt, insofar as possible, to relate and associate learning activities in science with other subjects in the curriculum.

POINT of VIEW
EARTH SCIENCE

RATIONALE

Earth science is a course designed to emphasize the underlying unity and the interrelationships of the earth sciences – astronomy, geology, meteorology, oceanography and physical geography. In method and approach, the subject should be presented through broad concepts which provide for logical correlations of the separate disciplines.

Current innovations, in the senior high science courses – BSCS, PSSC, CHEM, ESCP, CBA, and others during the past ten years, have fostered a definite trend toward specialization of science courses in grades 7-8-9 at the state and national levels. **It is recommended that the earth science course be offered at the eighth grade level.** A descriptive study, made in 1966, revealed that 376 of the 414 Missouri school administrators replying, favored the offerings of life science at the seventh grade level, earth science at the eighth grade level, and physical science at the ninth grade level. The study also indicated that the administrators concurred with the trend of specialization at the junior high level.

In 1963, the Earth Science Curriculum Project was organized by leading earth scientists and teachers with headquarters at the University of Colorado. As a result of this organization, an earth science laboratory manual for experimental use was distributed to pilot schools in 1964. A revision of this material is now being published for use in the nation's schools. This emphasis, coupled with similar projects in biological and other physical sciences, has resulted in establishing a definite trend toward specialization at the junior high level. (General science concepts will be emphasized at the elementary level.) Excellent textbooks and teaching aids are now available in this interdiscipline – earth science.

A recent inquiry of the fifty state departments of education revealed that those states not now offering a course in earth science indicate that their next revision will include this course. Many states replied to the inquiry by sending a teacher guide for earth science education. It is evident that a rebirth of interest in earth science, as a part of the junior high science program, has been rapid during the past five years. It is believed that teachers can now capitalize on this rebirth of interest resulting from recent development in the space exploration program. This interdiscipline fuses the sciences involved in space exploration and provides limitless opportunities for a laboratory-centered course. At this time, newspaper reports and periodical articles continue to whet the lively curiosity of the junior high age level.

It is recognized that this guide constitutes a first in Missouri with emphasis on earth science as a separate course. Heretofore, earth science has been presented in correlation with general science and seldom identified as a separate discipline. The primary intent of the Committee charged with the responsibility of developing this guide was (1) to develop a guide for teachers in keeping with the most recent trends in science education – self-discovery through pupil-participation in laboratory-centered approach, (see expectancies for further discussion), (2) develop a teaching device to aid teacher-trainers in the pre-training program of earth science teacher, and (3) to offer functional methods and approaches for implementing this course at the classroom level.

POINT OF VIEW

The Committee believes that the following basic expectancies are not only in keeping with the most recent trends, but also attainable goals at the classroom level.

Expectancies:

- The pupils should achieve an understanding of the earth's position in time and space.
- The pupils should possess a knowledge of the interdependence of living and non-living things and the constancy of change in each.
- The pupils should attain an initial understanding of the relationship between matter and energy – chemical composition of the earth, forms of energy and properties of matter.
- The pupils should achieve a functional knowledge of the geologic formations, time and change.
- The pupils should understand the basic principles of meteorology.
- The pupils should develop the skills related to laboratory experimentation – reporting, analysis of data, utilization of equipment and materials, etc.
- The pupils should gain a continuing interest in the method of inquiry as a means of solving problems.

The expectancies are based on the assumption that the course will be laboratory-centered with adequate equipment, materials and supplemental references. Broad concepts, the method of inquiry, and natural phenomena will be stressed and investigated. No school in Missouri is remote from nature's own laboratory; therefore, at least half of the course should be experience-centered laboratory work.

Status of Earth Science Teachers

The Committee recognizes the problem of trained teachers in earth science. Heretofore, the course has been in correlation with general science and therefore taught by teachers of general science. In the transition from general to specialization in science at this level, the course will no doubt be taught by the best trained general science teacher – five semester hours in earth science should be considered minimum. Eventually, acceptable credits in physical geology, historical geology, chemistry, physics, astronomy, rocks, minerals, and meteorology should constitute the basis of an adequately trained teacher of earth science.

It is estimated that by 1970, over 13,000 schools in the nation will offer a course in earth science at the secondary level with over one million pupils enrolled. If this expansion becomes a reality, at least 12,000 more teachers of earth science will be needed – 7,000 earth science teachers are now employed in the nation. It is evident that teacher training presents the basic problem. Teachers may become better prepared through summer science institutes, in-service workshops, and regular summer school offerings.

POINT OF VIEW

Since this course is recommended as an eighth grade offering, it is estimated that by 1970, over four hundred school districts, in Missouri, will offer the specialized sequence of life, earth, and physical science with about 60,000 eighth grade pupils enrolled in earth science.

In an age requiring a knowledge of conservation of natural resources, resource-use, and space exploration, it is readily discernible that a functional knowledge and understanding of the physical properties and processes of the earth and its relationship to the universe is imperative. It is believed that an earth science course offered at the eighth grade level will contribute greatly to meeting this universal need.

PROFESSIONAL RESPONSIBILITIES RELATIVE TO AN EARTH SCIENCE COURSE

I. Colleges and Universities

- Institute and improve course work for the training of earth science teachers
- Offer, whenever possible, National Science Foundation sponsored institutes and in-service institutes for up-dating teachers
- Offer resource facilities
- Serve in an advisory capacity

II. Board of Education

- Provide adequate science laboratories and equipment
- Employ skilled, well-prepared teachers
- Give teachers released time for in-service training
- Provide clerical and/or laboratory assistance
- Provide trained science consultants and/or resource personnel to whom the teacher may turn for help
- Formulate supportive curricular policies

III. Superintendents

- Encourage counselors to consider earth science one of three basic sciences
- Support teachers in their endeavors to implement innovative methods
- Guide boards of education in their support of innovations in science education
- Keep the board of education informed of new trends and curricular changes
- Encourage utilization of NDEA funds

IV. Consultants or Supervisors

- Make teaching materials and supplies available
- Be available to help teachers, when needed, especially beginning teachers
- Obtain new materials for teachers
- Teach "model" demonstration lessons
- Initiate or suggest new programs
- Assume a position of leadership, in the improvement of science education

V. Teachers

- Keep abreast of new developments in earth science curricula
- Set up demonstrations and experiments well in advance of class meetings
- Plan class work and evaluate progress
- Encourage student participation
- Be willing and receptive to trying new ideas and methods
- Aid in keeping the channels of communication open
- Maintain a professional attitude

VI. Counselors

- Acquaint themselves with the place of earth science as a part of the total science program
- Guide students into understanding the value of earth science education

INSTRUCTIONAL PROGRAM

STRUCTURE

This guide for teachers of earth science is structured in seven major areas of investigation as follows:

I. THE PRIMEVAL EARTH – "IN THE BEGINNING"
- formation of a layered earth
- formation of layered oceans
- formation of a layered atmosphere
- origin of primeval life

II. EARTH AND ENERGY – THE INVISIBLE EARTH
- the sun, primary source of energy
- solar radiation
- cosmic radiation
- the earth's fields
- gravitation and isostasy
- magnetic fields and the core of the earth

III. EARTH AND CHANGE – THE RESTLESS EARTH
- diastrophism, volcanism, mountain building
- earthquakes, earth structure, changing sea level
- interpreting the solid earth

IV. COMPOSITION OF THE EARTH – ROCK: WATER: AIR
- lithosphere
- hydrosphere
- atmosphere

V. EARTH CYCLES – AGAIN AND AGAIN
- the hydrologic cycle
- oceans and global circulation
- atmosphere
- weather and climate
- the rock cycle
- weathering and soil formation
- the erosional cycle
- sculpturing forces

VI. EARTH AND TIME – ALPHABET OF TIME AND LIFE
- superposition (a basic law)
- faunal and floral succession
- geologic time scale
- the atomic clock (absolute age)
- the geologic history of North America
- the geologic history of Missouri

VII. THE EARTH'S NEIGHBORS – FRONTIERS OF THE FUTURE
- the moon, the earth's satellite
- Mars
- Venus
- our distant planets
- stars and galaxies – back to the beginning

ORGANIZATION

Each area of investigation is organized on the unit basis as follows:

Rational – Presents the premise and overview of the unit.

Introductive Activity – A suggested activity which involves, insofar as possible, all pupils in a laboratory-oriented situation intended to serve not only as a motivative device, but also as an open-ended medium which leads to continuing related activities. The principles or concepts to be emphasized, equipment needed, suggested procedure, possible outcomes, underlined key words for vocabulary growth, anticipated continuing activities and references for readings are included in each unit. The **"How Do We Know"** phase of the unit may be used as a pre-motivating device and also as a method of leading into the introductive activities – further readings, experimentation, and demonstration.

The teacher should feel free to introduce the area of investigation with any one of the continuing activities or one of her choice, if it is more in accordance with the interest of the class. The basic intent of this method or organization is to aid the teacher in her transition from the cookbook-memorization-drill-test method, to the more modern approach to science education as heretofore emphasized.

The acceptance or the rejection of newer methods and approaches to science education, in the final analysis, is the responsibility of the individual teacher. Basically, the newer method requires the divergent concept of thinking and questioning, active pupil-participation, doing rather than telling,. analysis of information and data rather than memorizing facts and definitions, and the inductive approach rather than the deductive teacher-centered process. Administrators are encouraged to support and aid the teacher in this "from-to" transition. Without this support, there is less hope for lasting improvement in the instructional program.

Unit I. THE PRIMEVAL EARTH – IN THE BEGINNING

Rationale:

Man's interest in the planet, Earth, stems from his desire to understand the phenomena of nature. His inquiring mind has developed as a basic part of his character through ages of evolvement. Man first became interested in the earth for extremely practical reasons; for food, shelter, and clothing. Today he is still interested in the earth, but for different reasons; water and air pollution, conservation, and space exploration.

The student, upon completing the first unit, should be more nearly aware of the mighty forces of energy that shape the earth. He should be motivated to continue his study of additional units. This unit should provide an initial ledge of concepts that will be more fully explored in the units which follow.

How Do We Know?

In discussing geologic time, and the magnitude of time, the teacher should emphasize that interpretation is based on observation. For example, how was the Grand Canyon formed – earthquakes, glaciation, underground streams, surface streams? To motivate this interest, set up an abrasion table experiment using pebbles flowing in water over various types of soil. Ask the pupils to observe abrasion of rock in small streams, and collect rocks which show wearing by abrasion and weathering. Speculate regarding time required to form small stream beds, rivers, and canyons. It is understood that the "how do I know?" phase of the unit will require reading from texts, references, and contour maps.

Introductory Activity:

Basic Principle: The earth is very old, geologic time is immense and the natural earth processes, in operation today, have been at work throughout all of geologic time.

Equipment:

The primary principle pointed out at the beginning of this unit can best be illustrated through the study of the film, "In The Beginning," which relates the history of the Grand Canyon. This film, along with a 16mm. motion picture projector, will be needed for the unit. The teacher should also provide, for study purposes, tables of geologic time.

Procedure:

The teacher should preview the film prior to class, taking notes that will aid in class discussion. The instructor should discuss with the students their concepts relative to the immensity of time. For example, it might graphically be pointed out that the length of time that man has been on the planet, Earth, can be represented by the relative thickness of a dime atop the television tower on the Empire State Building, where the thickness of the dime represents man's tenure on earth and the height of the building and tower represents all of the remaining geologic time. A scale of geologic time should be discussed so that students grasp the meaning of eras and epochs. Students should not, at this time, be asked to memorize the geologic table. The purpose of this unit is to motivate and stimulate as well as to provide an initial "look" at geologic terminology. All students should become **involved.** It may very well be that some have visited the Grand Canyon on family vacations and will bring slides or pictures of the Grand Canyon.

Possible Outcomes:

After completing the work associated with this initial unit of study, the student should be able to explain the basis by which scientists have divided geologic time into major divisions. Students should have developed, through their study, a more realistic appraisal of the magnitude of time. They should also begin to grasp the point that a geologic scientist must constantly observe, interpret, weigh facts, and place in proper time perspective in order to arrive at the chronological sequence of the history of the earth.

Hopefully, students will become involved in the discussion of problems that are, as yet, unsolved. For example, theoretically the first sediments deposited in the abyss of an ocean basin should still be there because there are few currents to remove them. However, the oldest sediments on the sea floor thus dated are Cretaceous in age, apparently because sediments of greater age have been covered or destroyed by volcanic activity. Secondly, some scientists also believe that when the earth was molten, the granitic rock collected into one large mass. They believe that this "super-continent" later may have broken apart and drifted. What is the significance of the fact that the age of the oldest rocks yet measured on several continents are about the same? Why do the edges of South America and Africa seem to match? Can other continents be so matched?

Continuing Activities:

1. Students should be encouraged to grasp the immensity of time. The concept could be stressed by having the students figure the number of years that it would take for a clock to tick off a billion seconds.
2. Students may develop a panel discussion speculating: (a) What can man do about his changing environment? (b) How has the explosion of scientific knowledge affected man and his environment?
3. Students will get a better mental picture of the primitive earth and its neighbors in space by viewing a selection of films suggested at the end of the unit.
4. Students can be encouraged to make oral reports on theories related to the origin of the universe. Cross-examining teams can be appointed to question each report asking, "Does this theory answer the known facts about the nature of the universe?"
5. Students can be encouraged to collect photographs and make charts of the solar system.
6. Students can construct cut-away, three-dimensional models of the earth's interior from styrofoam.
7. A large weather balloon can be purchased for a few dollars. (Check classified advertisements in science periodicals.) This can then be inflated and painted as a gigantic globe. Such a "globe" is inexpensive, interesting to the students, and easily stored.
8. A geologist resource speaker can be obtained by contacting most college or university geology departments.

9. A laboratory utilizing the inquiry approach can be set up to acquaint students with "What is a rock?". Students can critically examine pieces of wood, coal, plastic, metal, chalk, etc. and note how these differ from rocks and minerals which should also be available. Students should utilize the scientific method in noting the differences that they are able to distinguish. The instructor should **give them a chance to discover. Do not,** for example, note on the board, "Today we will prove". This is not science. Let the students **inquire,** observe, and interpret.

10. A film, "Adjustments of the Scientists", may be used to demonstrate the work of earth scientists. This film depicts the recent geologic work accomplished by the second Byrd Expedition.

Fundamental Concepts:

- For every **fossil** the geologist can unearth, the **astronomer** can point his **telescope** to a **galaxy** whose light left there when that fossil represented a living organism.
- The **universe** is as old as any of its parts.
- The parts of the universe include the **elements,** the **planets,** and their satellites, the **stars** and the **galaxies.**
- As the young **planet Earth** cooled, water was squeezed from the newly solidifying rock.
- The ten most abundant **elements** in the earth's crust are distributed throughout the layers of the **Earth** and include: oxygen, silicon, aluminum, iron, calcium, sodium, potassium, magnesium, titanium, and hydrogen.
- At first **life** was neither strictly **animal** nor strictly **planet.**
- Few of the earliest organisms left preserved **fossils,** primarily because they had no **hard parts.**
- Because of changing environments, living organisms have continually undergone change.
- A unique set of **physical** and **chemical forces** may be at work in the interior of the earth.
- The **earth's crust** is very different from the material deep beneath it.
- The upper crust of the continents is largely **granitic** in nature, whereas the crust beneath the oceans is largely **basaltic.**
- Evidence indicates, at the present time, that the earth is more than **4½ billion years** old.
- Geologists refer to the solid earth as the **lithosphere,** the waters of the earth as the **hydrosphere,** and the gases above the earth as the **atmosphere.**

Films

"Adjustments of the Scientists"	18 min., b/w	Indiana University
"Beyond Our Solar System"	15 min., b/w	Coronet Films
"In The Beginning"	20 min., c	J.J. Hennessy Films, or Mobil Oil
"Story in the Rocks"	13 min., c	Shell Oil
"The Fossil Story"	29 min., c	Shell Oil

Filmstrips

"How Rocks Are Formed"	McGraw Hill
"Scanning the Universe"	Wards Science Est.
"The Earth and Its Wonders"	Wards Science Est.

Exhibits

Geological-Geographical Terms Relief Model	Wards Science Est.
Mueller-Ward Solar System Models	Wards Science Est.

Maps

Aero Raised Relief Map, North America	Wards Science Est.
Hammond Relief Map, United States	Hammond Company

Books and Pamphlets

Geologic Pamphlets (no charge)	Missouri Oil Council
Earth Science Series – Selected References – Selected Films – Selected Sources Information	Prentice-Hall, Inc.
"What is Geology?"	American Geological Inst.

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UNIT II – EARTH AND ENERGY – THE INVISIBLE EARTH

Rationale:

How empty is "empty" space? Only a few years ago such a question would have seemed ridiculous. Outer space was thought to be composed primarily of widely scattered atoms and molecules of certain gases. New discoveries have led to a startling conclusion: the earth orbits through an outpouring of ionized gases, atomic particles, cosmic rays and galactic cosmic rays coming from the sun, and galactic cosmic rays originating from beyond our solar system.

Theories of isostasy and studies of seismic waves, and gravitational, and magnetic forces have helped provide the basis for our understanding of mass distribution within the earth from which its structure and composition can be inferred. The earth's crust seems to be in a state of near equilibrium.

Introductory Activity:

Basic Principle:

It is important to understand why isolation (energy received by the earth from the sun's radiations) varies at different times of the day, at different latitudes, and at different seasons.

Equipment:

The following equipment will be needed:

protractor, radiometer, rule, slide projector, and a watch.

Procedure:

Part A. Place a radiometer in the beam of a slide projector so that one of the vanes of the radiometer is at right angles to the beam of light. Count the revolutions of one vane per minute and also record the distance between the slide projector and the radiometer. **Part B.** Repeat Part A but vary the distances between the slide projector and the radiometer. **Part C.** Replace the slide projector and radiometer at the original position (Part A). This time tilt the projector so it makes an angle of thirty degrees with the radiometer. Count the revolutions per minute and also record the distance between the slide projector and the radiometer. **Part D.** Repeat Part C, keeping the same angle of elevation between the projector and radiometer, but varying the distances the same as in Part B. Record these distances and revolutions of a vane per minute. **Part E.** Repeat Parts C and D, but first at an angle of sixty degrees then an angle of ninety degrees. Record these date in either a table or graph form.

Possible Outcomes:

Students should discover that the sun radiates energy at a nearly constant rate. The intensity of solar radiation varies with the distance and inclination of the sun relative to the earth. This intensity of radiation varies inversely with both the distance and the inclination. The average yearly radiation which reaches the earth is greatest at the equator and least at the poles due primarily to the sun's inclination. The concentration of the sun's rays and the angle of inclination at which these rays strike the earth is more significant than distance. Therefore, the Northern Hemisphere has the greatest solar radiation during summer solstice and least during winter solstice, although the earth's distance from the sun is greatest in our summer by three million miles.

Continuing Activities:

1. The teacher can compare the energy received from infrared and ultraviolet radiation by using a slide projector and radiometer.

2. Students can demonstrate that light energy can be converted into heat energy by mounting two thermometers, one each, on a sheet of cardboard. Set each of these in the sunlight, but remember to cover only one of the thermometers with a jar – the greenhouse effect.

3. The instructor can secure several isogenic maps from the Army Map Service. Or it may be more interesting to have the students draw their own maps.

4. The earth's magnetic field may be illustrated by:

   Part A. Using iron filings to illustrate magnetic lines of force.
   Part B. The effect that a magnetic field has on a compass.
   Part C. Using a magnetic compass and demonstrating the laws of polarity.
   Part D. Constructing and then illustrating the magnetic dip needle.

5. Make a gnomon by using a pole's shadow each day at the noon hour. This should show the sun's elevation on a daily basis.

6. Show the effects of the interaction between the forces of inertia and gravity.

7. Show and illustrate the orbital path of planets and satellites.

8. Illustrate the revolving of objects about their centers of mass by throwing a wrench or similar object.

Fundamental Concepts:

- The amount of **insolation** per unit area upon the earth is determined by the **angle of inclination** and length of time the sun's rays shine per day. Both factors are governed by the **latitude** of the particular location.

- **Light intensity** decreases as the distance from the source increases.

- Sunlight is a form of **radiant energy,** as are **x-rays, ultraviolet rays,** vibration of **photons,** and **infrared rays,** which are believed to be released as a result of the **fusion** of **hydrogen** atoms forming **helium** atoms.

- Sunlight itself has no **temperature** until it is absorbed by some form of matter. During the **hydrogen to helium reaction** some matter is converted into light and energy.

- The sun's immense radiant energy is believed to consist of photons which move as waves. This concept combines some of the **wave theory** and some of the **corpuscular theory** and is called the **quantum theory.**

- **Ionization** of the atmospheric gases is caused by the impact of **electrons, protons** and **neutral particles** or by **cosmic rays** from the sun.

- Cosmic rays are more powerful as ionizers than is sunlight. The intensity of cosmic rays, upon reaching the earth, is influenced by **sunspots,** the earth's **magnetic field,** and the **ionosphere.**

- **Ions** are very active because they are electrically unbalanced and tend to become balanced by adding or losing electrons.

The radiation belts composed of electrically charged particles trapped within part of the earth's magnetic field are called magnetosphere or Van Allen Belts. These trapped particles spiral between the magnetic poles, making doughnut-shaped belts.

Every body in the universe attracts every other body with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distances between them. (Newton's Law of Universal Gravitation.)

- Variations of **gravity** on the earth's surface are dependent upon **altitude, latitude,** and **densities** of the earth's material at that location.

- The earth's magnetic poles appear to have wandered in a somewhat circular path around the **geographic poles.**

- The earth's magnetic field is produced by internal and external forces and acts as a magnet near the earth's center.

- In a period of one **year,** both the earth and the sun revolve around their common center of mass. This point is located near the center of the sun.

- Both the earth and moon revolve around their common center of mass in a period of one **month.** This center of mass is located within the earth.

- The revolution of the earth, sun and moon, about their center of mass, causes a point on the earth to experience the maximum and minimum in **tide-generating** force.

- **The Mohorovicic discontinuity** is the interface between the **crust** and **mantle.**

- The earth consists of an **outer crust,** a layer called the mantle, an outer liquid-like shell of high density, and possibly a very dense solid inner core.

- The state of balance of the earth's crust is explained by the theory of **isostasy.** To aid in explaining the theory of isostasy, geologists have advanced the contraction theory, the convection theory, and the expansion theory.

Films:

"Cosmic Rays"	20 min., c	McGraw-Hill Text Film
"Elliptical Orbits"	20 min., b/w	Modern Learning Aids
"Magnetic Forces"	29 min., b/w	McGraw-Hill Text Film
"Nuclear Radiation In Earth Science"	15 min., c	Cenco Educational Films

"Our Mr. Sun"	68 min., c	Bell Telephone System
"The Strange Case of The Cosmic Rays"	53 min., c	Bell Telephone System
"Universal Gravitation"	32 min., b/w	Modern Learning Aids

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Unit III – EARTH AND CHANGE – THE RESTLESS EARTH

Rationale:

Since its beginning billions of years ago, the earth has been constantly changing. Forces have been at work raising the surface of the earth and at the same time other forces have been working to lower the surface. The total effect of these forces results in a continually changing earth. This unit will explore these forces, their causes, and the results brought about by these forces. The instructor should keep before the students, the questions "How do we know?" and, "What is the evidence?".

Introductory Activity:

Basic Principle:

At any given time, some parts of the earth's surface are being raised while other parts are subsiding.

Equipment:

Large, flat container for water (about 10" wide and 3" deep), blocks of wood of various sizes and densities, sawdust or iron filings, and a ruler.

Procedure:

Float the blocks of wood in the water and measure the part of the block extending out of the water. Compare the distances of those blocks of like densities and different thicknesses. Then compare those of different densities and like thicknesses. Place some sawdust or iron filings on some of the blocks and remeasure. Record all data.

Possible Outcomes:

It should be realized that the blocks of different densities serve to represent rocks of different types and blocks with different thicknesses represent rock columns of different lengths. The sawdust or iron filings represent different rock sediments. Rocks of different densities and thicknesses cause crustal movement. As sediments build up, the increasing weight causes movement of the crust. The crust of the earth is not floating on liquid, but does rest on a somewhat plastic material. The student should be encouraged to understand isostasy, which is the equilibrium achieved by upward and downward movement of the crust. Although rocks are solid, they appear to flow when under pressure for long periods of time.

Continuing Activities:

1. "Silly Putty" or modeling clay can be obtained locally and can be used to show how many of the land features are formed.
2. A field trip can be arranged to some nearby area where erosion, weathering, and faulting can be observed. Such a field experience can give the student a better understanding of these processes.
3. The instructor can have blocks of wood cut at various angles. These can serve as fault models.

4. A seismograph can be constructed. Directions for a simple one can be found in many geologic books or periodicals.

5. Topographic maps of seismic or volcanic regions can be obtained from the United States Geological Survey, Washington 25, D.C. These may be used to study particular areas which show various types of land forms. The quadrangle of Crater Lake, Oregon and of Harrisburg, Pennsylvania are exceptionally good.

Fundamental Concepts:

- The earth has been constantly changing for billions of years. Some of these changes take place rather quickly (hundreds or thousands of years), but most of them take very long periods of time. Evidence for this can be seen where large cross-sections of the earth are exposed; for example, the Grand Canyon. Rock here can now be aged, or dated, by rather accurate means.
- **Vulcanism** and **diastrophism** are uplifting or constructional forces.
- **Constructional forces** produce major land forms.
- **Major land forms** consist of mountains, plateaus, and plains.
- **Mountains** may be formed by the folding rock layers into **anticlines** and **synclines.**
- Mountains may also be formed by **faulting.**
- When diastrophism uplifts the crust, keeping it level, **plateaus,** or **plains** are formed. These land features may also be formed by erosional processes.
- Faulting is one of the causes of **earthquakes.**
- Most vulcanism takes place inside the earth and certain **intrusive activities** may produce **laccolithic** mountains when magma causes the upheaval of overlying sedimentary beds.
- Vulcanism is most readily observed through its **extrusive activities** which results in **volcanic cones, lava flows,** and **lava plateaus.**
- Erosion and weathering are destructional forces.
- Destructional forces produce minor land forms such as **valleys, water gaps, waterfalls, caves,** and **cliffs.**
- Erosion removes and carries away weathered material and deposits these sediments forming **flood plains, deltas,** and **sand bars.**
- The agents of erosion are running water, wind, waves, currents, and glaciers.
- Weathering causes rock to be broken into smaller particles by **mechanical** and **chemical** means.

EARTH AND CHANGE

Films:

"Birth of a Volcano"	10 min., b/w	Syndicated Films
"Eruptions of Kilauea Volcano"	18 min., c	U.S. Geological Survey
"Volcanoes Action"	10 min., b/w	Encyclopedia Britannica
"Earthquakes and Volcanoes"	18 min., c	Film Associates of California
"Earthquakes"	10 min., b/w	Alminac Films
"Mountain Building"	10 min., b/w	Encyclopedia Britannica
"Wearing Away of the Land"	10 min., b/w	Encyclopedia Britannica
"Work of Rivers"	10 min., b/w	Encyclopedia Britannica
"Geological Work of Ice"	10 min., b/w	Encyclopedia Britannica

Filmstrips:

"Volcanos and Earthquakes"	color	Society for Visual Education
"Mountains"	color	Society for Visual Education
"Changing Surface of the Earth"	color	McGraw Hill
"Our Earth is Changing"	black/white	Jam Handy

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UNIT IV – COMPOSITION OF THE EARTH – ROCK, WATER, AIR

Rationale:

Earth science is the study of man's environment. To most students, the solid earth under their feet ranks high in interest and importance. A knowledge of the earth's composition and structure provides a cultural background for man's appreciation of the world's scenic wonders. The earth's mineral resources supply a basis for our expanding industrial civilization. Water resources and the gases of the atmosphere make plant and animal life possible, as we know it, on our planet. It is not only the awe-inspiring beauty of the earth that enriches one's personality, but even more the evidence of stability and order helps to create a sense of security within us. Since man's horizons are now broadened to include the entire universe, a basic understanding of the planet Earth, upon which we live, is essential.

Introductory Activity:

Basic Principles:

- The crust of the lithosphere is composed of many rock-forming minerals, but relatively few are common.
- A mineral is a natural-occurring element or inorganic compound having a definite chemical composition and marked by characteristic physical properties.
- An element is a substance that cannot be broken down into simpler substances by ordinary chemical means.
- A compound is composed of two or more elements chemically combined.
- A mixture is made up of two or more substances physically, but not chemically combined.
- A rock is an aggregate of minerals constituting an appreciable part of the earth's crust.

How Do We Know?

Where a new road cut has been made through a section of old sedimentary deposits, geologists may learn much about the rocks and minerals making up the various layers. From a layer of shale, for instance, he can deduce that this soft, crumbly rock must have been deposited in a shallow sea, perhaps not far from shore. A layer of limestone indicates that this spot was once at the bottom of a calm, quiet sea where shellfish flourished and buried the bottom deep with fragments of their shells, which were later formed into limestone by the pressure of succeeding deposits.

In the laboratory, scientists have measured the uranium-to-lead ratio in various igneous rocks, gaining a fairly good idea of the time when different igneous rocks solidified.

The study of field samples of thin sectioned rock leads to the conclusion that these particles are not random mixtures, but rather homogeneous substances with definite physical and chemical characteristics. When the same mineral particles are found in many parts of the earth, the conclusion may be drawn that the substances making up the greater part of the earth's crust are relatively few in number. Deposition in shallow water and progressive subsidence may be inferred from sediments stacked many thousands of feet thick. Fossils demonstrate the development of living things through the long ages of earth's history, from the more primitive to the more complex forms of life.

A chemical analysis of many rocks and minerals has established the fact that 98% of the earth's crust by weight consists of only eight elements.

Equipment:

The following equipment should be provided:

Powdered sulphur, iron filings, toothpicks, small gumdrops, several shoeboxes, stereoscopic (3D) microscope, hand lenses, penny, knife, steel file, pieces of glass about 4 sq. inches, platform balance, weights, two-equal-sized (small) tin cans, water, string, hydrochloric acid (dilute) with eyedropper, paper towels, unglazed tile, bar magnet, small amounts of several powdered minerals including magnetite, black light (quartz or argon lamp), Bunsen burner, test tubes, blowpipes, platinum wire, borax, Geiger counter, geologist's hammer.

The following mineral samples are suggested: (Demonstration samples should be relatively large, but those in student's shoeboxes may be smaller.)

Agate, apatite, augite, azurite, barite, bauxite, biotite, calcite, chalcedony, chalcopyrite, native copper, chert or flint, chlorite, dolomite, fluorite, galena, graphite, gypsum, halite, hematite, hornblende, jasper, kaolin, limonite, magnetite, malachite, muscovite, olivine, orthoclase, plagioclase, pyrite, quartz (crystal and rocky), serpentine, sphalerite, sulphur, talc, and perhaps one or two radioactive minerals.

Rock and mineral collections may be obtained from Ward's Natural Science Establishment, P.O. Box 1712, Rochester, New York, or from Eckert's Mineral Research, 110 East Main Street, Florence, Colorado.

Procedure:

To introduce and arouse student interest in the activity, the film **"Rocks and Minerals"** from Film Associates of California, 11014 Santa Monica Boulevard, Los Angeles, California, may be used. The filmstrip **"Minerals: How They Are Identified"** is also excellent. It may be obtained from Filmstrip of the Month Club, 355 Lexington Avenue, New York.

If these are unavailable, a teacher-led discussion of the formation, composition, distribution, and economic importance of minerals may introduce the activity. Suggested references: **Earth Science, The World We Live In,** Namowitz and Stone, 1965, Van Nostrand, 120 Alexander Street, Princeton, New Jersey, Chapters 1-3.

The best classification of minerals into broad groups is on the basis of their chemical composition. The meaning of elements, atoms, compounds, and mixtures should be discussed. The atomic structure of typical elements may be explained by means of blackboard drawings, charts, and models. Models of elements may be constructed of toothpicks and small gumdrops. A common chemical classification of minerals is elements, oxides, hydroxides, chlorides, carbonates, sulphates, sulphides, and silicates. Large demonstration samples of each of the chemical groups may be used. A less complex classification of minerals is to divide them as **rock-forming or metallic.**

At the next, and succeeding sessions, each student should have a mimeographed list of approximately 35 common minerals with chemical symbols and several identifiable characteristics noted. A shoebox kit, containing a dozen or more numbered samples should be supplied for every two or three students, depending on class size. Stations for testing various characteristics of minerals may be set up in the laboratory. The instructor should explain that not all specimens will respond to the tests.

Station 1: Crystal Structure: A stereoscopic microscopic, hand lenses or tripod magnifiers. Note shapes and sizes of crystals.

Station 2: Hardness: Use fingernail, penny, knife blade, steel file, thick piece of glass – Mohs Scale of Hardness should be explained and posted at this station.

Station 3: Specific Gravity: Balance, beakers, string, ringstand, tin cans, weights, water. Concept of density should be developed first. Demonstrate specific gravity and explain that it is a number which represents the ratio between the weight of a given substance and the weight of an equal volume of water.

Station 4: Acid Reaction: Small bottle of diluted hydrochloric acid and eyedropper. Should be near a sink with water and paper towels.

Station 5: Streak Determination: Several pieces of **unglazed tile.** Streak refers to the color of the mark which a mineral leaves when a small amount is powdered by abrasion on the tile. The bottom-side of an old dinner plate is a convenient source of unglazed tile.

Station 6: Magnetic Properties: Bar Magnets. Powdered bits of a mineral may be attracted to a magnet better than a larger piece. Small-sized paper staples are attracted to magnetic minerals.

Station 7: Phosphorescence, Fluorescence: If a small darkened storage space is available, set up a black light (quartz or argon lamp) and teach students how to use it.

Station 8: Flame Tests, Blowpipe Tests, Borax Bead Tests: Bunsen burner, test tubes, blowpipes, platinum wire, powdered minerals, borax. Explain and demonstrate first.

Station 9: Radioactive Properties: Geiger counter. Explain and demonstrate first.

Station 10: Fracture or Cleavage: Geologist's hammer, large samples of a few minerals.

Station 11: Color and Luster: This may be performed at the student's laboratory table, or where good light is available. Point out that color alone is a rather poor basis for identification.

Suggested Identification Table

Mineral	Color Fracture Cleavage	Streak	Sp. Gravity	Hardness	
Feldspar $KA1Si_20_8$					Luster
Quartz $Si0_2$					Acid Reaction
Calcite $CaC0_3$					Fluores. or Phos.
Olivine $(MgFe)_2 Si0_4$					Radio-activity
Gypsum $CaS0_4H_20$					Crystal Structure
Sphalerite ZnS					Flame tests
etc.					

Note: If wide paper is used, all column heads will fit on one sheet.

Recommended books to be used by students as aids in identification include:

Earth Science: The World We Live In (see p.3), **Modern Earth Science,** Ramsey and Burckley. 1965. Holt, Rinehart and Winston, Inc., 383 Madison Avenue, New York, Ch.10-11 and Appendix **Rocks and Minerals** by Zim and Shaffer. 1962. Golden Press, 1 West 39th Street, New York.

Possible Outcomes:

Observation and experimentation with mineral samples probably offers the most valid and interesting approacn to learning this phase of the earth's composition. In this method, the student uses the scientific method and develops habits of independent thought.

The errors discovered through the student's testing of his hypotheses leads to critical thinking and retention. Careful and accurate observation and testing by students leads to more valid conclusions with fewer errors and misconceptions.

Continuing Activities:

1. The instructor may use globes both regular and cut-away; charts, and maps to develop concepts of the earth's three spheres.

2. Modeling clay of three colors is excellent for making a cross-section of the earth's interior.

3. Crystals of copper sulphate, potassium alum, barium chloride, salt, and sugar may be grown in jars in the laboratory and examined under the stereomicroscope.

Carefully planned field trips are an integral part of understanding both lithosphere and hydrosphere. Every area in Missouri has cliffs, road cuts, streams, lakes, or ponds. Information gained on field trips and enthusiasm engendered, are retained far beyond the study of the unit. It is possible to follow the geologic rock sequence from Precambrian to Recent in crossing Missouri from southeast to northwest. The Missouri Geological Survey, at Rolla, will provide information on possible **area** field trips.

4. Students should be encouraged to make rock and mineral collections.

5. Students may classify and identify rocks, including as many as possible of the following: **Igneous:** granite, babbro, felsite, basalt, obsidian, pumice, tuff, rhyolite, andesite, pegmatite, syenite, diorite, and various lavas. **Sedimentary:** limestone, sandstone, shale, conglomerate, breccia, coal (organic). **Metamorphic:** marble, slate, quarzite, gneiss, and several schists.

6. The teacher may demonstrate the formation of compounds and mixtures.

7. Students may find and identify different crystal shapes in minerals.

8. A comparison of igneous and sedimentary rocks with their metamorphic equivalents can be made.

9. A bar graph may be constructed to show the relative abundance of the eight elements making up 98 percent of the earth's crust.

10. The simplest demonstration of compounds and mixtures may be performed by the students themselves using powdered sulphur, iron filings, and a magnet. They may sprinkle iron filings on filter paper and then pass a magnet over the filings. Then spill some powdered sulphur on another filter paper, and pass a magnet over it. Now mix the two elements. Since this is a mixture, the iron filings will readily separate and cling to the magnet. Then, the teacher may mix 5 grams of powdered sulphur and 7 grams of iron filings in a test tube and heat until it glows. When the compound is cool, wrap it in a cloth and break the test tube, showing that a new compound, iron sulphide, has been formed. Then test with the magnet to show that it is non-magnetic.

11. **Student reports** may include the following topics: Project Mohole, Metallic and Non Metallic Minerals, Unequal Distribution of Earth's Available Fresh Water, World Water Shortages, Desalinization, Scuba Diving, Farming of the Continental Shelf, Undersea Discoveries from Bathyscaphe and Bathysphere, Ocean Floor Topography, Comparison of Atmospheres of Earth and other Planets, Exploration of Atmospheric Layers by Satellites and Weather Balloons, Conservation of Diminishing Mineral Resources, and Search for New Mineral Deposits.

COMPOSITION OF THE EARTH

Fundamental Concepts:

- The basic composition of the earth may be considered as consisting of three spheres, the **lithosphere,** the **hydrosphere,** and the **atmosphere.** To some extent, the three spheres permeate each other.
- Since earth's deepest mines extend only about two miles, and the cores extracted during oil well drilling do not exceed five miles, man's direct knowledge of the lithosphere is extremely limited.
- The **crust,** varying in thickness from about three miles, under the oceans, to forty miles beneath mountain masses, is composed of **basaltic** rocks with a **specific gravity** of 3.0 under the oceans, and **granitic** rock with a specific gravity of 2.7 under the continents.
- The **mantle,** extending some 1800 miles inward, is composed of more dense rock with a specific gravity of about 5.
- The outer shell of the **core** of somewhat **plastic** iron and nickel extends about 1,350 miles farther, and the inner core of solid iron and nickel extends 800 miles to the earth's center. The specific gravity of the entire core probably averages between 12 and 15.
- The solid earth bulges slightly at the equator, and in shape resembles an **oblate spheroid.**
- The **Mohorovicic Discontinuity** marks the rather abrupt change between the crust and the mantle.
- More than 2,000 minerals of the earth's crust have been identified, but only a few compose the major part of the crust.
- Most minerals are combinations of **elements** which probably formed as the earth cooled from its molten state. **Oxygen, silicon,** and **iron** are by far the most abundant.
- Approximately six to ten common minerals form the rocks which make up 90 percent of the earth's crust.
- **Igneous** rocks have been formed by the solidification of molten material , while **sedimentary** rocks have been formed by the **compaction** and **cementation** of **fragmental** material or by **precipitation** of material from **solution. Metamorphic** rocks are formed by the **alteration** of existing rocks through the action of heat, pressure, and **permeating** fluids.
- Water is the only natural occurring substance that exists as a solid, a liquid, and a **vapor** under ordinary conditions on earth. Water probably first appeared on earth as a vapor, then condensed as the molten rock of the earth slowly congealed.
- As the earth slowly cooled, rain probably fell for many eons, filling the ocean basins.
- Water now covers approximately three-fourths of the earth's surface.

COMPOSITION OF THE EARTH

- The **topography** of the ocean floor resembles that of the earth's surface with great **ridges, abyssal plains,** slopes, volcanic peaks **(seamounts),** trenches and **guyots.**

- The total **relief** of the earth is approximately thirteen miles, since the deepest trench measures nearly seven miles and the highest peak above sea level on the surface is less than six miles in altitude.

- The earth's atmosphere is divided into **concentric** spheres which are believed to extend as far as 22,000 miles. This is the greatest distance at which atmospheric gases still rotate with the earth.

- The **Homosphere,** extending to about fifty-five miles, is a uniform mixture of gases, consisting principally of **nitrogen** and oxygen together with small amounts of **argon, carbon dioxide, krypton, xenon, helium, hydrogen,** and **ozone.** Variable amounts of water vapor are present.

- The **Heterosphere,** consisting of layers of different gases such as nitrogen, oxygen, helium, and hydrogen, contains molecules so highly scattered as to form almost a **vacuum.**

- Within the Homosphere the **Troposphere** extends from the earth's surface to five miles at the poles and eleven miles at the equator, or to the top of the **convection** currents. Here the earth's weather is born. The temperature drops steadily with increasing altitude.

- Strong, steady winds blow within the **Stratosphere,** which extends to approximately thirty miles and has a rather constant temperature (-70°F). Here, the sun's radiation breaks down the oxygen molecules, which re-form as ozone molecules, protecting the earth from too much **ultraviolet radiation.** There is no dust, no color and no weather. In the lower levels, the powerful **jet stream** encircles the earth.

- The **Mesosphere** continues upward to approximately fifty-three miles, with steadily dropping temperature to -150 degrees F.

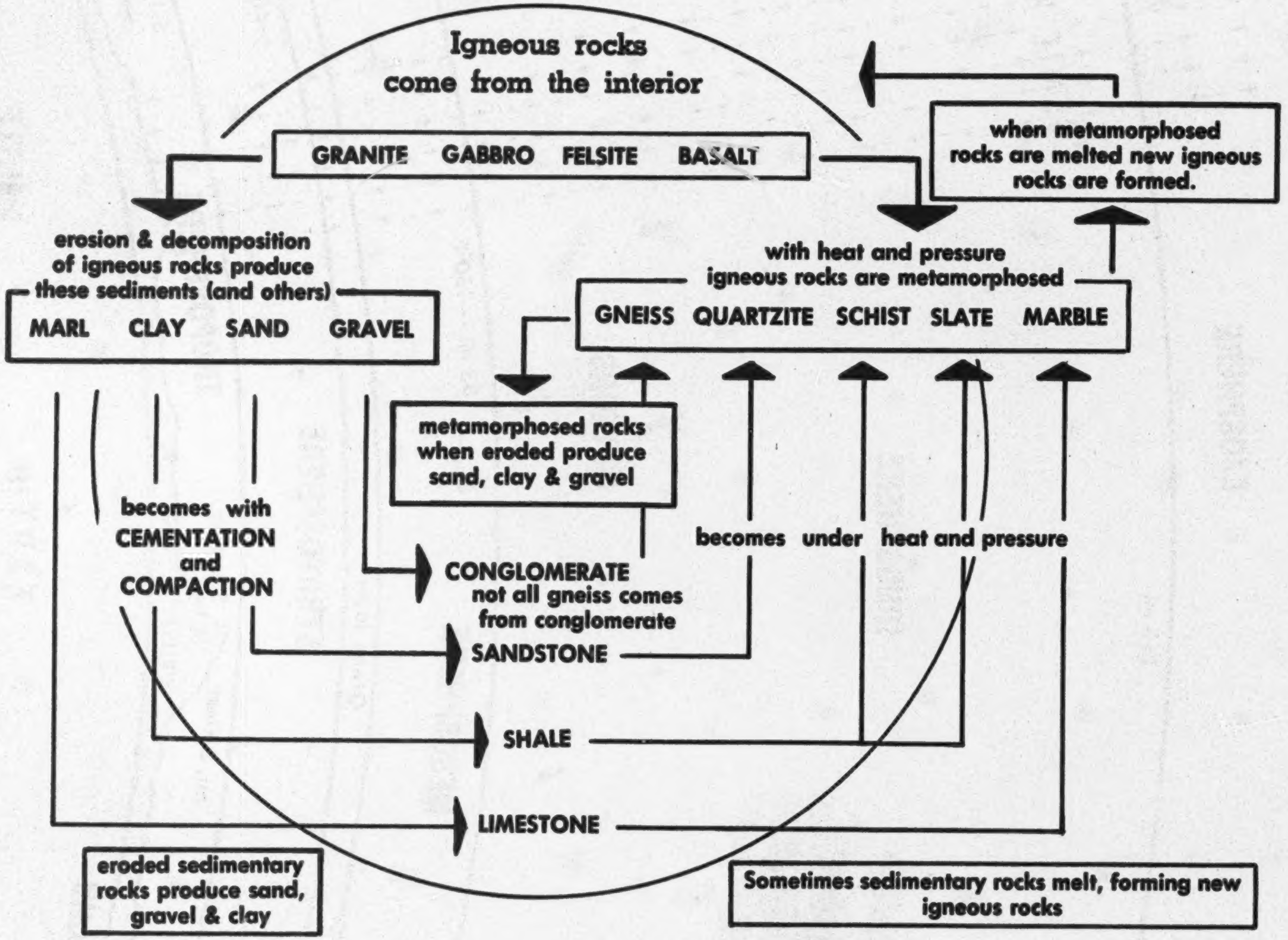
- In the **Ionosphere,** the beginning of the Heterosphere, the particles of nitrogen and oxygen are ionized or electrically charged. Electrical discharges provide the source for the Auroras. The Ionosphere may extend to 600 miles with temperatures reaching several thousand degrees.

- Beyond the Ionosphere lies the **Exosphere,** extending to about 40,000 miles and trapping **cosmic rays** in its **magnetic field.** These high energy particles produce the doughnut-shaped Van Allen belts of radiation.

Recommended Films: (Addresses of sources listed in Appendix)

"Caverns and Geysers"	14 min., c	Film Associates of California
"Challenge of the Oceans"	27 min., c	Planet Earth Series, McGraw-Hill Text Films
"Earth in Change"	16 min., c	Encyclopedia Britannica
"Explaining Matter Atoms and Molecules"	14 min., b/w	Encyclopedia Britannica
"Face of the Earth"	12 min., c	Encyclopedia Britannica

THE ROCK CYCLE


Igneous rocks
come from the interior
GRANITE
GABBRO
FELSITE
BASALT
erosion & decomposition of igneous rocks produce these sediments (and others)
MARL
CLAY
SAND
GRAVEL
becomes with CEMENTATION and COMPACTION
when metamorphosed rocks are melted new igneous rocks are formed.
with heat and pressure igneous rocks are metamorphosed
GNEISS
QUARTZITE
SCHIST
SLATE
MARBLE
metamorphosed rocks when eroded produce sand, clay & gravel
CONGLOMERATE
not all gneiss comes from conglomerate
SANDSTONE
SHALE
LIMESTONE
becomes under heat and pressure
eroded sedimentary rocks produce sand, gravel & clay
Sometimes sedimentary rocks melt, forming new igneous rocks

COMMON MINERALS

ELEMENTS

copper, sulfur
graphite

SULFIDES
Galena, Sphalerite,
Chalcopyrite, pyrite
OXIDES, HYDROXIDES
Hematite, Limonite,
Bauxite, Magnetite
HALIDES
Halite, Fluorite
CARBONATES, NITRATE
BORATES
Calcite,
Colomite
Malachite
Borax
SULFATES
Barite Gypsum

specimens can be mounted under name of each rock and mineral for added effect

SILICATES

Olivine
Serpentine
Chalcedary
Hornblende

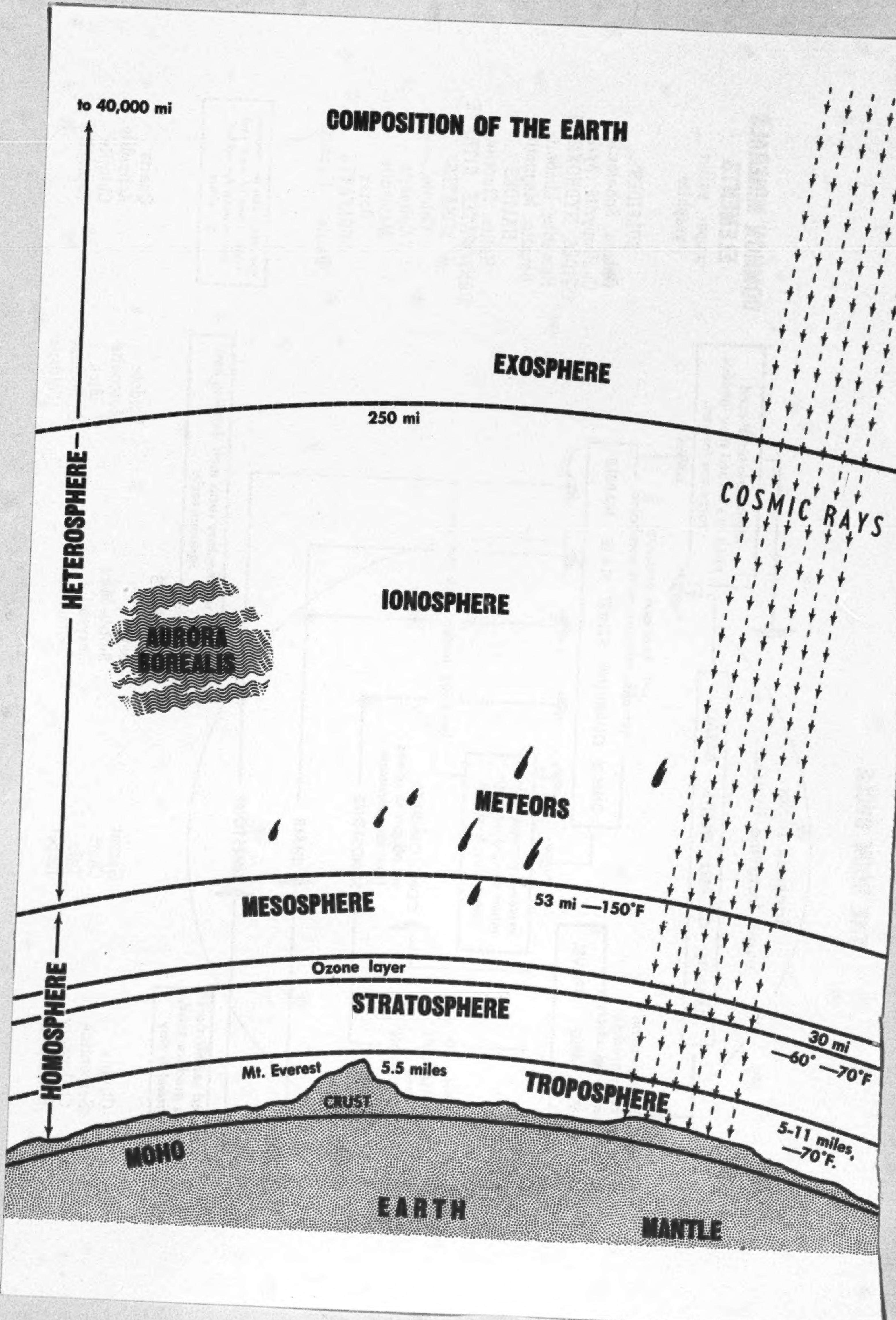
Garnet
Chert
Talc
Jasper

Beryl
Biotite Mica
Chrysotile
Tourmaline

Epidote
Muscovite
Mica
Orthoclase
Feidspar

Quartz
Actinolite
Chlorite
Lepidolite

COMPOSITION OF THE EARTH


to 40,000 mi
EXOSPHERE
250 mi
HETEROSPHERE
COSMIC RAYS
IONOSPHERE
AURORA BOREALIS
METEORS
MESOSPHERE
53 mi —150°F
Ozone layer
STRATOSPHERE
30 mi
—60° —70°F
HOMOSPHERE
Mt. Everest
5.5 miles
CRUST
TROPOSPHERE
5-11 miles,
—70°F.
MOHO
EARTH
MANTLE

COMPOSITION OF THE EARTH

"Flaming Sky"	27 min., c	Planet Earth Series, McGraw-Hill
"Force of Gravity"	27 min., c	Planet Earth Series, McGraw-Hill
"Hidden Earth"	27 min., c	Planet Earth Series, McGraw-Hill
"In the Beginning"		John J. Hennessy Productions
"Lead from Mine to Metal"	15 min., b/w	U.S. Bureau of Mines
"Magnetic Force"	27 min., c	Planet Earth Series, McGraw-Hill
"Mountain Building"	11 min., b/w	Encyclopedia Britannica
"Restless Sea"	50 min., c	Walt Disney Productions
"Rocks in Our Neighborhood"	13 min., c	McGraw-Hill Text Films
"Rocks for Beginners"	16 min., c	Johnson Hunt
"Science of the Sea"	19 min., c	International Film Bureau
"What's Inside the Earth"	15 min., c	Film Associates of California
"What's Under the Ocean"	15 min., c	Film Associates of California

Filmstrips:

"Common Minerals"	S. Visual Education
"Composition of the Air"	Jam Handy

Exhibits:

Set of Rocks and Minerals of Missouri (obtained from Missouri Geological Survey, Rolla). (Free, one to a school.)

Charts:

American Oil Institute (suitable for bulletin boards).
Rock and Mineral Chart (may be easily constructed of plyboard).

(Should be large, about 4 sq.ft., making possible the use of relatively large samples of the minerals and if perforated plyboard is used, samples may be attached with fine wire.)

Maps:

Geological map of Missouri – Missouri Geological Survey, Rolla

Books and Pamphlets: (these are primarily for student use)

Barnett, Lincoln and Editors of Life. 1955. **The World We Live In,** Simon and Schuster, One W. 39th Street, New York.

Farb, Peter, 1963. **The Face of North America,** Harper and Row, 49 East 33rd Street, New York.

Finch, Vernon C., et. al. 1959. **The Earth and Its Resources,** McGraw-Hill, 330 W. 42nd Street, New York, Chapters 8 and 14.

Gamow, George, 1963. **The Planet Called Earth,** Viking Press, 625 Madison Avenue, New York.

Holden, Allen and Singer, P. 1960. **Crystals and Crystal Growing,** Doubleday and Co., Inc., 575 Madison Avenue, New York.

Keller, Walter D. 1961. **Common Rocks and Minerals of Missouri,** University of Missouri, Columbia.

Namowitz, S.P. and Stone, D.B. 1965. **Earth Science: The World We Live In,** D. Van Nostrand, 120 Alexander Street, Princeton, New Jersey.

Tolsted, L. and Swinford, A. 1957. **Kansas Rocks and Minerals,** Kansas Geological Survey, Lawrence, Kansas.

Zim, H.S. and Shaffer, P.R. 1957. **Rocks and Minerals,** Golden Press, Inc., One West 39th Street, New York.

References: (primarily for teacher)

American Geological Institute. 1962. **Dictionary of Geological Terms,** Doubleday and Co., 575 Madison Avenue, New York.

Compton, Robert R. 1962. **Manual of Field Geology,** John Wiley & Sons, 440 Park Avenue, South, New York, Chapters 12-15.

Croneis, C. & Krumbein, W.C. 1961. **Down to Earth,** University of Chicago Press, 5750 Ellis Avenue, Chicago, Chapters 3,5,8,9,13,14,19,22,24,27.

Eardley, A.J. 1965. **General College Geology,** Harper & Row, 49 East 33rd Street, New York, Chapters 1-4, 6,9,10.

Earth Science Curriculum Project. 1965. **Investigating the Earth,** Prentice-Hall, Englewood Cliffs, New Jersey.

Emmons, William H., et. al. 1960. **Geology: Principles and Processes,** McGraw-Hill, 330 West 42nd Street, New York, Chapters 5,7,9,18.

Fagan, J.J. 1965. **View of the Earth, An Introduction to Geology,** Holt, Rinehart & Winston, 383 Madison Avenue, New York. Chapters 3-9.

Gamow, George. 1959. **Matter, Earth, and Sky,** Prentice-Hall, Inc., Englewood Cliffs, New Jersey, pp. 367-69, 373-81, 391-97, 410-11, 417-23.

Heller, Robert L., Ed. 1962. **Geology and Earth Science Sourcebook,** Holt, Rinehart & Winston, 383 Madison Avenue, New York. Chapters 1,2,9,11,16,17,18,19.

Koenig, John W., Ed. 1961. **Stratigraphic Succession in Missouri,** Geological Survey and Water Resources, Rolla, Missouri.

Pearl, Richard M. 1960. **Geology** (College Outline Series), Barnes and Noble, Inc., 105 Fifth Avenue, New York, Chapters 2,3,7,8,15.

Strahler, Arthur N. 1965. **The Earth Sciences,** Harper & Row, 49 East 33rd Street, New York, Chapters 19-22.

Stone, Donald B. 1964. **Discovery Problems in Earth Science,** College Entrance Book Co., 101 Fifth Avenue, New York, Topics 10,21.

Unklesbay, A.G. 1955. **Common Fossils of Missouri,** University of Missouri, Columbia (Missouri Handbook No. 4).

flask and the other end into a test tube surrounded by ice in a beaker. Boil the water in the flask.

Place a small amount of water and some smoke in a gallon jug. Place a two-hole stopper in the jug. Connect a small squeeze-bulb pump to one hole and a rubber hose outlet tube to the other hole. Pump air into jug while the outlet hose is pinched off. Release pinchcock quickly and observe. Close outlet hose and pump again Try the procedure again without adding smoke or dust to the jug.

Possible Outcomes:

From this activity, students should understand the hydrologic cycle better. They will understand the great involvement of this cycle with weather. They will see water evaporate, condense, and precipitate due to the addition and removal of heat. They will see water condense and evaporate because of heat changes caused by pressure changes. The students will conclude also that water is purified by evaporation, since the salt and coloring matter will remain in the distilling flask while the precipitated water is colorless and not salty. Reduction in pressure will cause adiabatic cooling and condensation of water vapor in air with high relative humidity. The value of condensation nuclei will also be shown in the cloud jug. Students may want to further investigate the change of water. They may want to try to boil tap water at room temperature with a vacuum pump and bell jar. If equipment is available, water can be made to exist in its three states simultaneously.

Continuing Activities:

1. Students can investigate relative humidity by using a hygrometer or sling psychrometer and the proper printed tables.
2. Students should determine the relative humidity by the dew point method.
3. Several groups of students can determine the rate of evaporation of water by varying such conditions as: relative humidity, sunlight, and air movement.
4. Convection currents in fluids can be demonstrated by using a convection tube apparatus and by placing the mouths of two bottles of unequal temperatures together. One of the bottles of water must be dyed with a coloring agent.
5. Unequal heating of the earth's surface can be shown by placing soil, water, etc. in equal volumes under flood lamps and periodically recording temperatures.
6. Changing climates may be caused by precession. A gyroscope or a spinning top can be used to visualize precession of a spinning object.
7. The greenhouse effect can be shown by placing two identical containers in the sun; placing thermometers in each with only one covered with glass.
8. Students can experience Coriolis effect by attempting to draw a straight line from the center of a piece of paper on the rotating turntable of a record player. A drop of water may be placed near the North pole of a spinning globe to illustrate the same thing.

9. Students can learn a lot about the conditions responsible for weather by individually collecting data such as temperature, pressure, relative humidity, wind speed, and direction using simple instruments which they or the school can secure. A month's subscription of weather maps from the U.S. Weather Bureau would be helpful.

10. Weathering of rocks may be shown by heating, plunging into water, and then by treating with acid.

11. Soil maps and soil surveys from 1899 to present may be secured and examined, especially if the school is in a rural area. Lists of available maps may be ordered from the United States Department of Agriculture, Washington D.C.

12. The effect of stream velocity on gradation can be shown by syphoning water from an elevated pail into a trough, which sand and gravel have been placed near the elevated end. Vary the size of the syphon and the slope of the trough.

13. Students can map contour lines by using plastic hill models and plastic shoeboxes. The plastic "shoebox" is marked at ¼-inch intervals, then the box is filled and the hill marked alternately at each interval. Essentially the same thing may be done by slicing a large potato in half and putting the flat side to a paper and drawing around it, then cutting off a slice of potato and repeating until the potato is cut away,and the contour map of the potato remains on the paper.

14. Topographic maps (contour maps) may be secured from the U.S. Geological Survey. It would be more interesting to the students if these maps were representations of the area near their homes, or if they represent various interesting landscape features. Maps of quadrangles in the State of Missouri may be secured from the Missouri Geological Survey, Rolla, Missouri.

15. Something can be learned about the movement of ground water if the students find, by experimentation, the amount of water that a certain volume of soil will hold. They should find the volume of water held by soils of various particle size.

16. Measure the relative volume of water that can move through sand of a various particle size.

17. The effect of pressure on the melting point of ice can be shown by hanging a wire over a block of ice. The wire is weighted on both ends. A clue to glacier movement is discovered by this illustration of regelation.

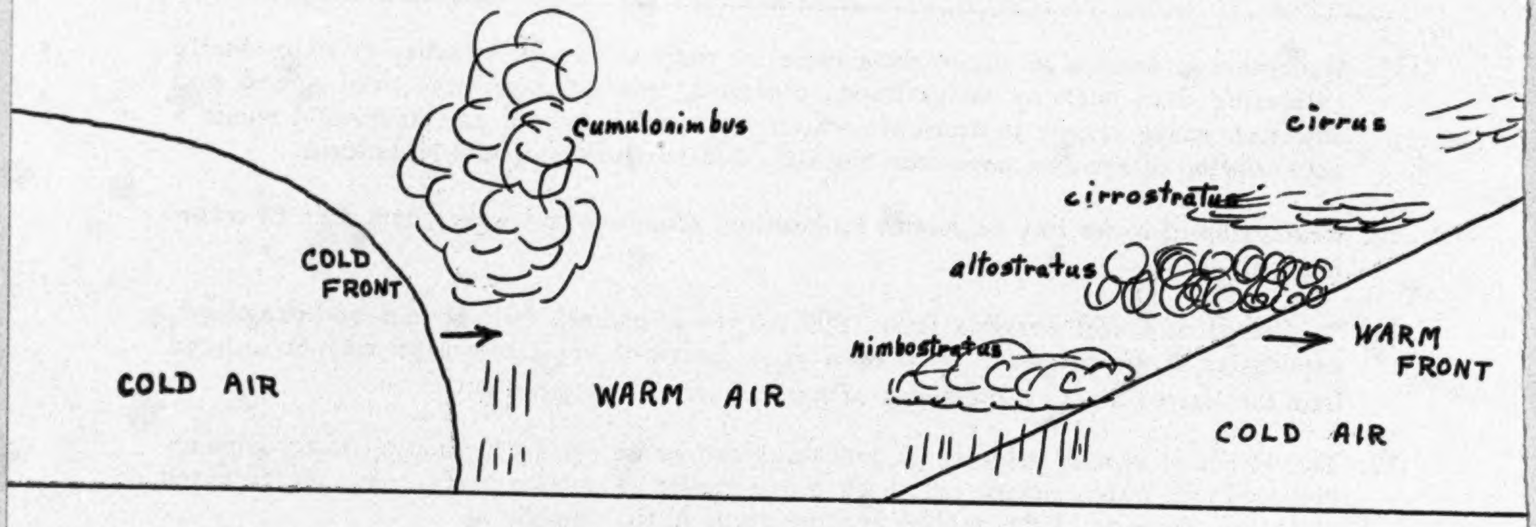
18. Students can observe how glaciers can erode by rubbing an ice cube over a board and then rubbing an ice cube which has been dipped in sand over the board. The term striae can then be introduced.

Fundamental Concepts:

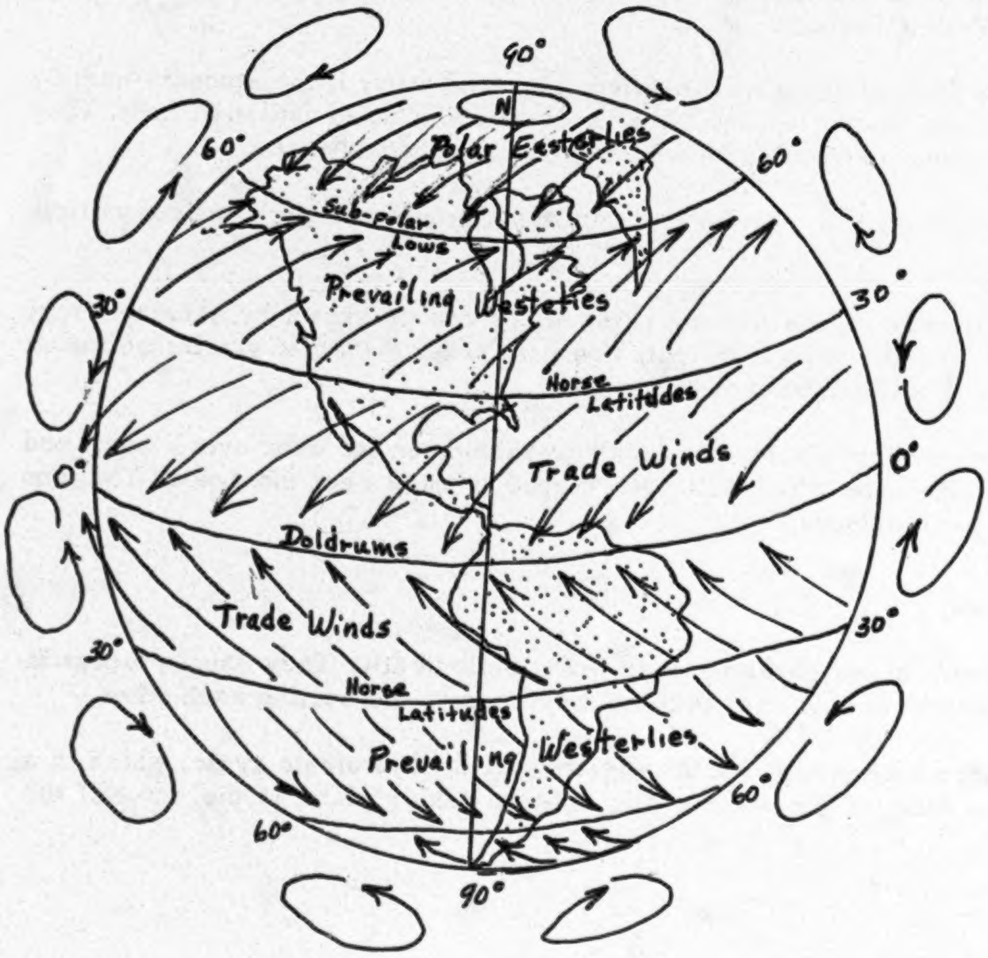
Many of the events in our changing earth occur periodically. They usually occur in **cycles** over a vast amount of time and space as they interact and overlap each other.

- The sun provides such energy for the operation of the **hydrologic cycle,** which is a major factor in many of the other cyclic changes taking place in the crust of the earth.

EARTH CYCLES

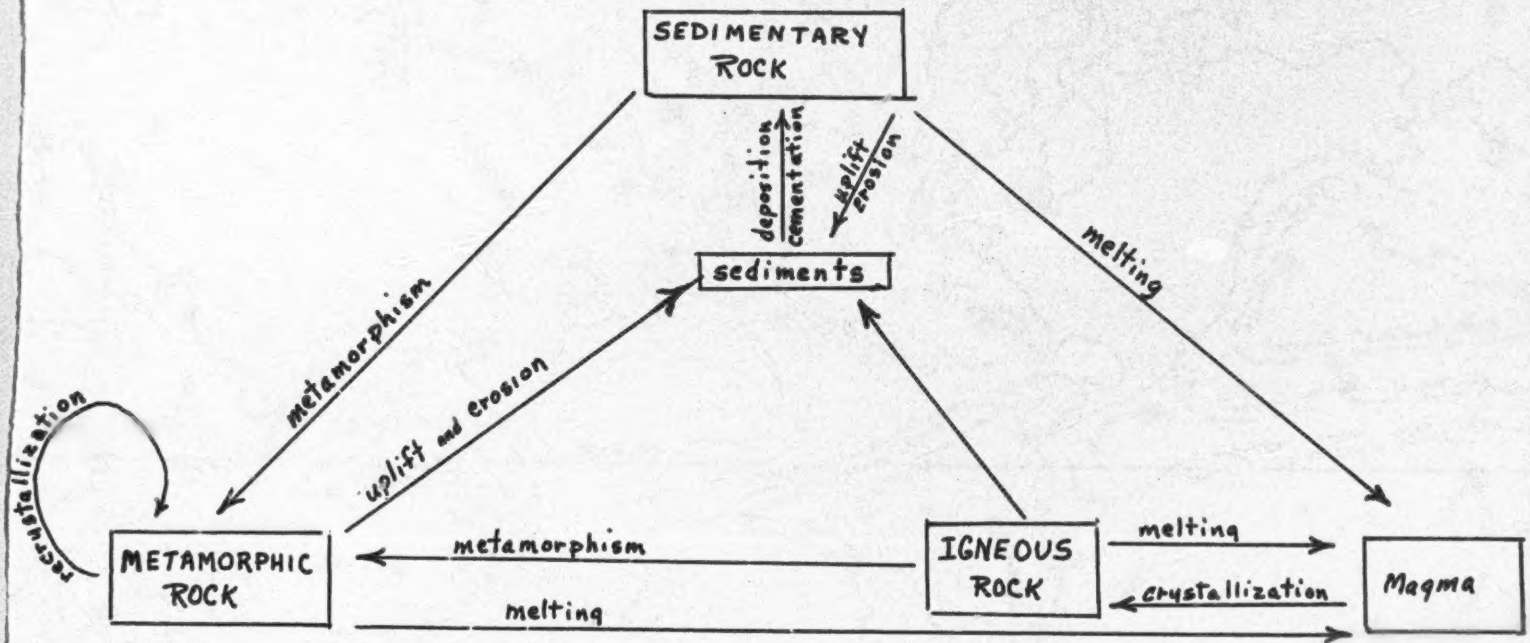

Cumulonimbus
cirrus
cirrostratus
COLD FRONT
altostratus
nimbostratus
WARM FRONT
COLD AIR
WARM AIR
COLD AIR

FULLY DEVELOPED WAVE CYCLONE

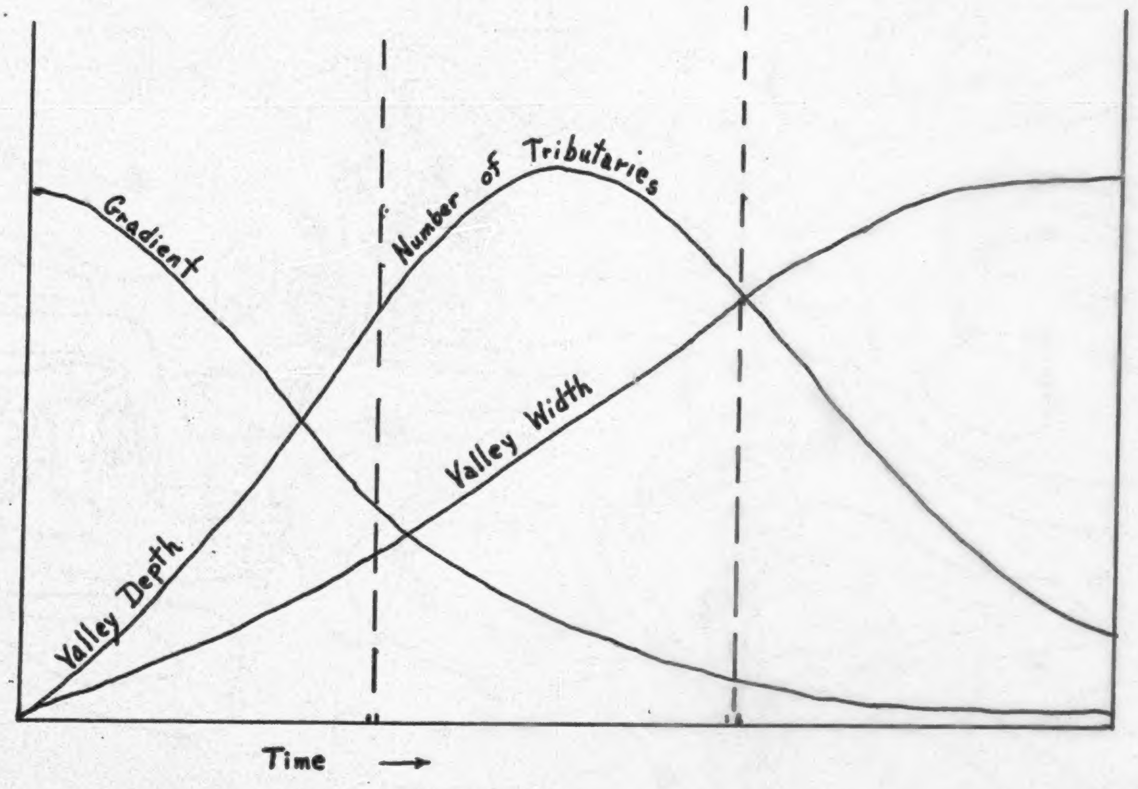

90°
N
Polar Easterlies
60°
60°
Sub-Polar Lows
Prevailing Westerlies
30°
30°
Horse Latitudes
Trade Winds
0°
0°
Doldrums
Trade Winds
30°
30°
Horse Latitudes
Prevailing Westerlies
60°
60°
90°

PREVAILING WINDS

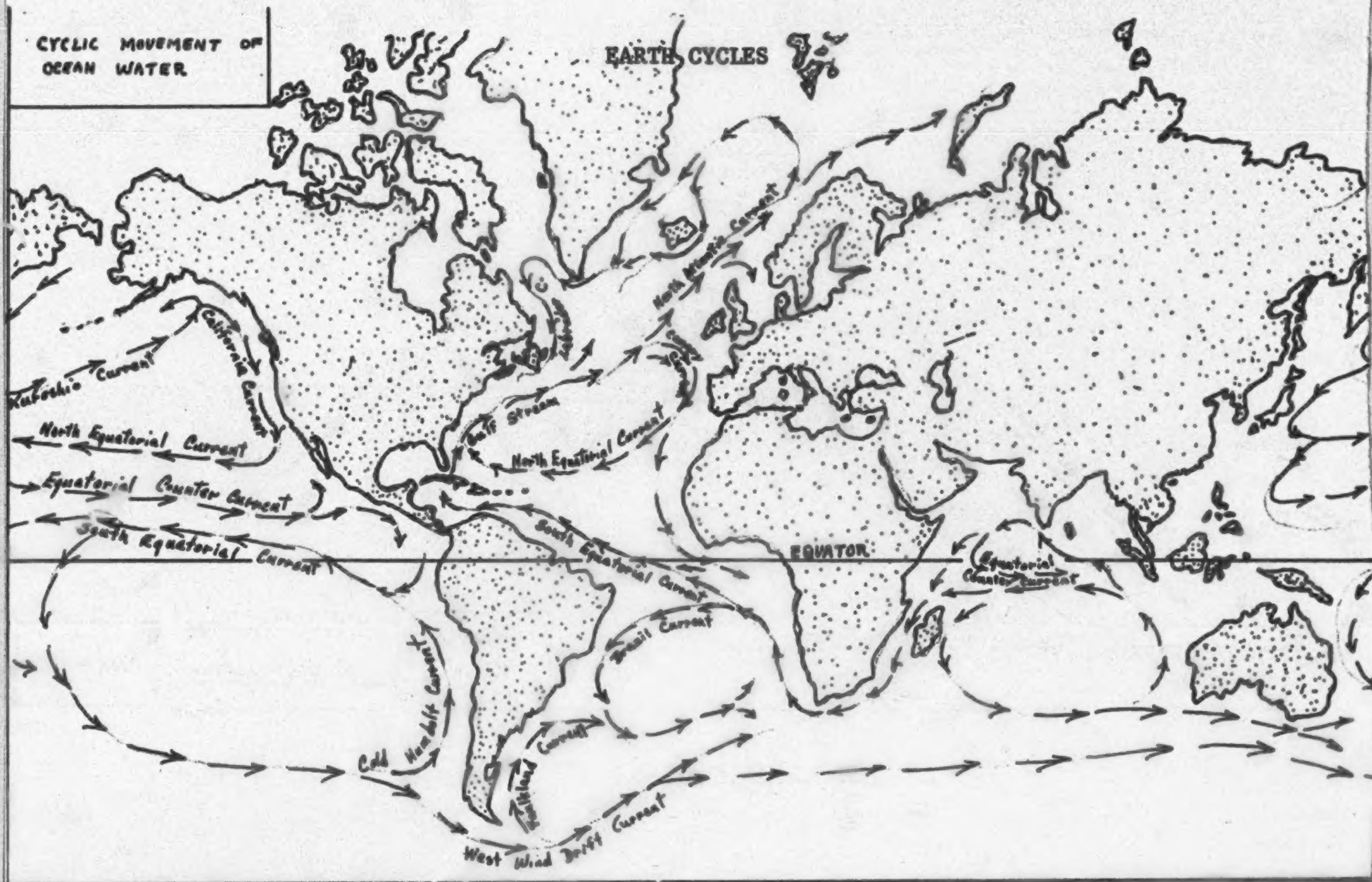
EARTH CYCLES

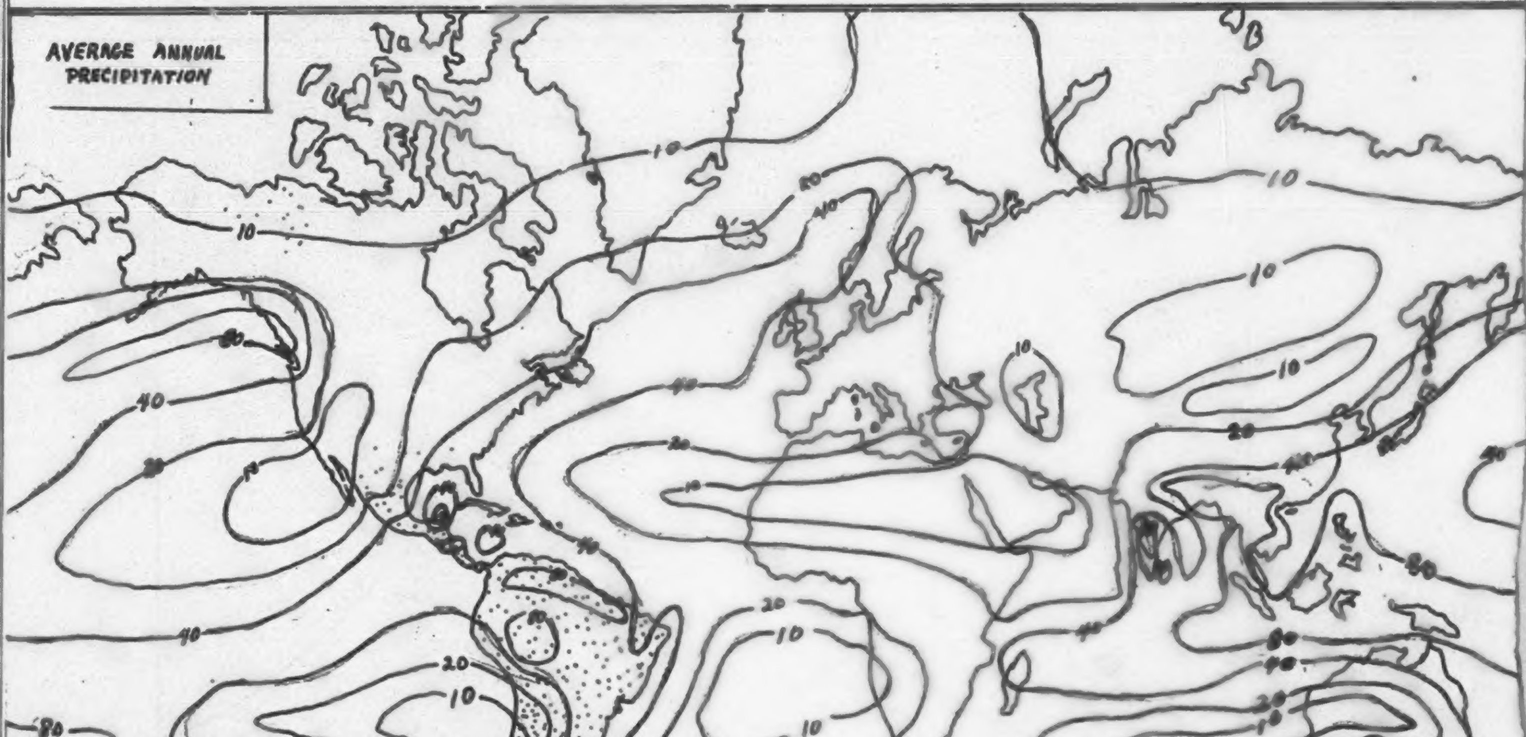

SEDIMENTARY ROCK
deposition
cementation
uplift
erosion
sediments
melting
metamorphism
uplift and erosion
recrystallization
METAMORPHIC ROCK
metamorphism
IGNEOUS ROCK
melting
crystallization
Magma
melting

THE ROCK CYCLE



THE STREAM CYCLE


CYCLIC MOVEMENT OF OCEAN WATER
EARTH CYCLES
Kuroshio Current
California Current
North Equatorial Current
Equatorial Counter Current
South Equatorial Current
Gulf Stream
North Atlantic Current
North Equatorial Current
South Equatorial Current
EQUATOR
Equatorial Counter Current
Brazil Current
Cold Humboldt Current
Falkland Current
West Wind Drift Current


AVERAGE ANNUAL PRECIPITATION
10
20
40
80

EARTH CYCLES

- The operation of the hydrologic cycle produces the status of the atmosphere which we call **weather.**
- The movement of air (the vehicle of water vapor) can be attributed to a **pressure gradient,** which is attributable to unequal heating of the earth's surface and the **Coriolis** effect.
- Unequal heating of the earth's surface is caused by uneven concentration of the sun's rays at all times over the surface of the earth as a result of the earth's rotating axis not being perpendicular to its plane of revolution, and by differences in surface structures which reflect heat and light at different rates.
- Water has a much higher **specific heat** than soil, rock, or organic matter and therefore warms more slowly and cools more slowly than land masses.
- Water vapor is moved over the earth's surface by convection currents called **winds,** which are caused by unequal densities of various air masses. These unequal densities are caused by differences in **temperatures, relative humidities,** and **altitudes** and are measured by **barometers.**
- Changes in temperature and pressure of air cause **condensation** and eventually **precipitation** of water from the air.
- Storms occur when **air masses** of varying relative humidities and temperatures meet in fronts.
- Cyclonic waves (lows), in the north hemisphere, develop along a polar front, resulting in an inward counter-clockwise air movement forming a cold and warm front which results in gentle rains lasting for several days, followed by frontal thunderstorms. This warm front is followed by a **cold front** with more rapid rising of the warm moist air resulting in violent storms as the air rapidly cools to and below its **dew point.**
- Descending winds of an **anti-cyclone** (high), rotate outward in a clockwise direction, resulting in fair weather.
- Climate is the average weather over a given area during a period of time and is affected by **latitude,** altitude, prevailing winds, **topography,** and **ocean currents.**
- The **Gulf stream** and other ocean currents cycle hundreds or even thousands of miles, giving stored heat energy to the air or taking heat from the air, thereby moderating climates of such areas as Northern Europe.
- Climates are cyclic, that is, they change through geologic time and in so doing influence the **erosion cycle** of which the **rock cycle** is a part. The **precession** theory partially explains climatic cycles.
- Water is continually shifted from one place of storage to another. It shifts from surface storage to the **zone of aeration,** and to the zone of saturation by **evapotranspiration** to the atmosphere where **condensation** takes place and **precipitation** to the surface again occurs.

- Lakes, though shortlived, are important in the storage of water, but if they extend to the **water table** in **arid** regions, they may lower the level of the water table.

- **Weathering** changes rocks to soil by altering their size with its physical agents, and their composition with its **chemical agents.**

- **Gradation** is the part of the rock cycle in which weathered particles are transposed and deposited by the agents of **erosion.**

- **Lithification** of sediment forms **sedimentary rocks.** These **stratify** because of changing conditions and varying materials being deposited over the long period of their formation.

- The pressure of sediments and depths of burial probably are contributing factors in the melting of all classes of rock to form **Magma,** which cool either **extrusively** or **intrusively** to form various kinds of **igneous** rocks.

- High pressures on sedimentary, igneous, or metamorphic rock may cause realignment of the crystals; and the intense heat and hot solutions may alter the rocks chemically and physically to form **metamorphic rocks.**

- There are several agents active in the erosion cycle which move uplifted materials to **base level** (sea level), but absolute leveling of an area is seldom complete.

  The rate and amount of erosion depends upon many factors, including: average rainfall, altitude, types of materials being eroded, rate of runoff, and average temperatures.

- Gravity produces **mass wasting,** which moves rock to lower levels.

- Running water is an important agent of erosion and the **landscapes** it forms contain **streams** which lengthen, widen, and lower their **valleys.**

- The typography of a single river system may show the **youth, maturity,** and **old stages** of the stream cycle in different locations throughout the stream's drainage area.

- The velocity of a stream, which is dependent upon its gradient, determines its ability to use its abrasive tools to erode, and its ability to move large particles.

- While gradation by running water is in progress, **ground water** is also undermining the landscape by dissolving materials and depositing this material elsewhere.

- Ground water may travel for hundreds of miles underground as it does in the **aquifers** responsible for the **artesian** conditions of the Great Plains, or it may travel only a few hundred feet underground and surface as an ordinary **hillside spring.** Its travel is slower than surface water because of the **friction** it encounters in the pores and cracks in the rock.

- **Ocean waves** are at work leveling the land as the wind creates waves, which transport and rearrange materials along the shore.

- In regions where more snow falls than melts, it is converted to ice and forms **glaciers.** Glaciers are not entirely limited in their modification of landforms by base level.

- **Valley glaciers** and **continental ice sheets** deposit similar loads of **till** forming **drumlins** and **moraines** as they melt; the melt water leaves **glaciofluvial** deposits.

- Landscapes modified by **valley glaciers** are rugged, but **continental glaciers** have smoothing effects as can be seen in Northern Missouri and areas generally, north of the Missouri and Ohio Rivers.

- The agent **wind** also leaves its mark upon the land as it moves over rock and soil carrying rock particles as tools, abrading rock, causing "blowouts" in some locations, and depositing **loess** elsewhere.

- Landscapes may show evidences of all the agents and stages of erosion, but because the forces of **vulcanism** and **diastrophism** are lifting land, the cycle is never complete, and there will always be land above the sea.

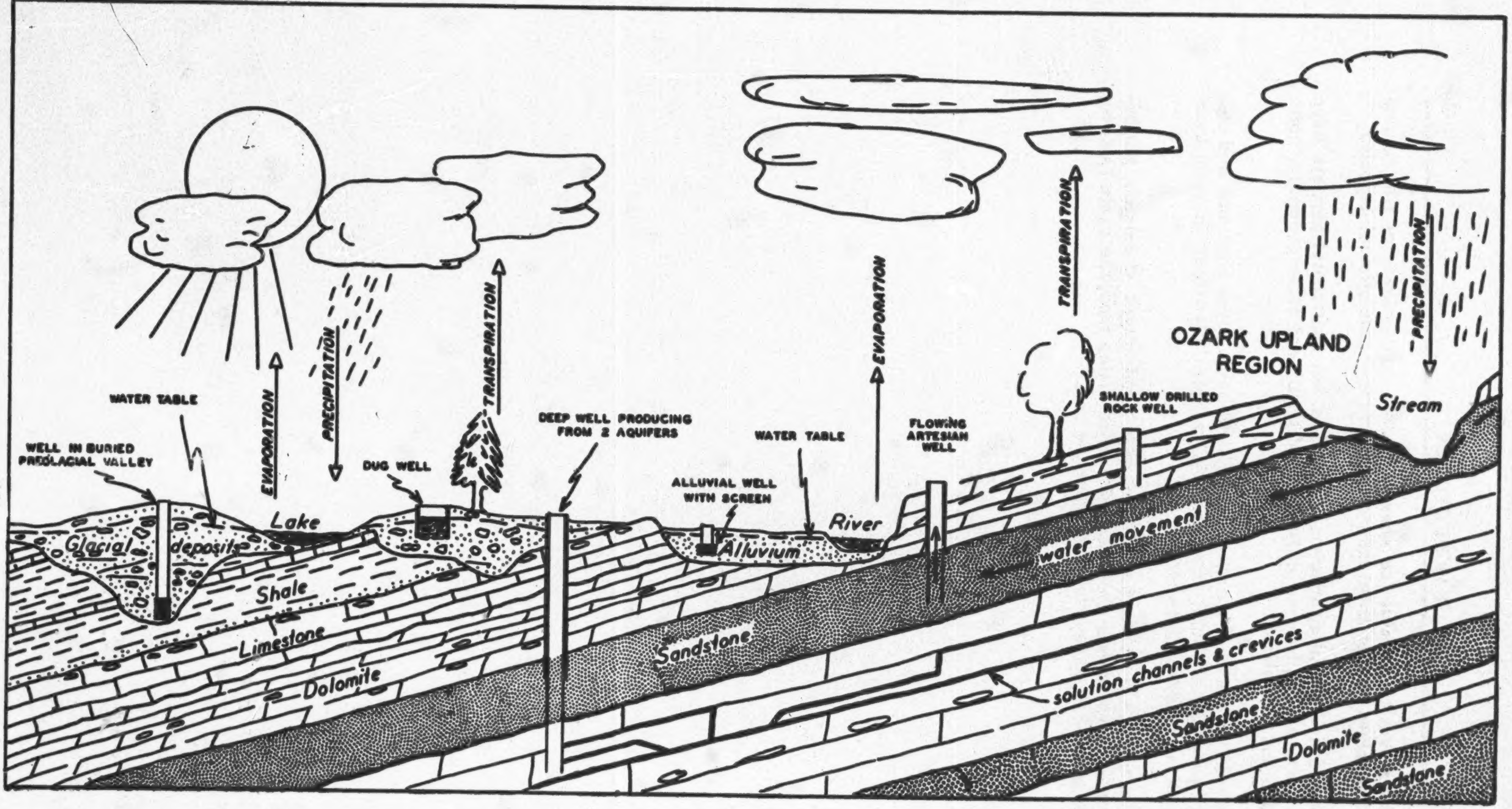

WATER TABLE
WELL IN BURIED PREGLACIAL VALLEY
EVAPORATION
PRECIPITATION
Lake
DUG WELL
TRANSPIRATION
DEEP WELL PRODUCING FROM 2 AQUIFERS
Glacial deposits
Shale
Limestone
Dolomite
ALLUVIAL WELL WITH SCREEN
WATER TABLE
Alluvium
River
EVAPORATION
FLOWING ARTESIAN WELL
TRANSPIRATION
SHALLOW DRILLED ROCK WELL
OZARK UPLAND REGION
PRECIPITATION
Stream
water movement
Sandstone
solution channels & crevices
Sandstone
Dolomite
Sandstone

DIAGRAM SHOWING IMPORTANT PHASES OF THE HYDROLOGIC CYCLE (INCLUDING EVAPORATION AND PRECIPITATION); GROUND WATER OCCURRENCE IN UNCONSOLIDATED (ALLUVIAL AND GLACIAL) DEPOSITS AND IN BEDROCK LAYERS; VARIOUS TYPES OF WATER WELLS; AND WATER MOVEMENT IN A DIPPING AQUIFER UNDER ARTESIAN CONDITIONS. ADAPTED FROM FIG. 3. ILL. GEOLOGICAL SURVEY CIRCULAR 232, BY W.B. HOWE, MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES. FEBRUARY 1958

EARTH CYCLES

Films:

"Face of the Earth"	12 min. c	Encyclopedia Britannica
"The Great Lakes – How They Were Formed"	11 min. c	Encyclopedia Britannica
"Continental Glaciers"	16 min. c	Ohio State University
"In The Beginning"	28 min. c	Socony – Mobil Oil Co.
"Limestone Caverns"	11 min. c	Coronet Films
"Tides and Currents"	16 min. c	U.S. Department of Commerce
"Unchained Goddess"	58 min. c	Bell Telephone Company

Filmstrips:

"Earth's Atmosphere"	McGraw-Hill
"Weather and Jet Streams"	McGraw-Hill
"Climates"	McGraw-Hill
"How Rocks are Formed"	McGraw-Hill
"Our Everchanging Earth"	Society for Visual Education
"Physiographic Change"	Harper, Row and Company
"Work of Ground Water"	Society for Visual Education
"Work of Snow and Ice"	Society for Visual Education
"Work of the Sea"	Society for Visual Education

Charts:

DGS11 **The Science of the Earth,** Chart No. 3, **Relationships of the Earth and Sun**
DGS11 **The Science of the Earth,** Chart No. 7, **Wind Systems of the Earth**
(The above prepared by Denoyer-Geppert Co.)

Maps:

North America	Any book company
United States	Any book company
Missouri	Any book company
World	Any book company
Soil Maps	U.S. Dept. of Agriculture
Weather Maps	U.S. Weather Bureau

State Index maps showing all quadrangle topographic maps available for each state may be obtained from the U.S. Geological Survey at no cost.

Boothbay Quadrangle, Maine	15 min.	Introduction to topographic maps
Campti Quadrangle, Louisiana	15 min.	Oxbow lakes
Cedar Creek Quadrangle, Montana		Alluvial fan
Charleston Quadrangle, W. Virginia	15 min.	Mature valley
Chief Mountain Quadrangle, Montana	30 min.	Valley glaciation
Columbia Quadrangle, Missouri		Karst topography
Donaldsonville Quadrangle, La.		Natural levees
Harrisburg Quadrangle, Penn.	15 min.	Water gap, folded mountains
Ironton Quadrangle, Missouri	15 min.	Old precambrian topography
Madison Quadrangle, Wisconsin	15 min.	Glacial lakes and swamps
Mammoth Cave Quadrangle, Ky.	15 min.	Karst topography

Red Rock Quadrangle, Washington	15 min.	Landslide
Soda Canyon Quadrangle, Colorado	15 min.	Young valley
Taughannock Falls Quadrangle, N.Y.		Delta
Tom's River Quadrangle, N.J.	15 min.	Shoreline
Whitewater Quadrangle, Wisconsin	15 min.	Continental glaciation
Yuma East and West Quadrangles California & Arizona	7½ min.	Sand dunes

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Unit VI – EARTH AND TIME – ALPHABET OF TIME AND LIFE

Rationale:

Geologic time is vast; no one can imagine the extent of a million or a billion years. For example, man has existed on the earth about one million years. This is only a small fraction of the total history of the earth, yet to man it represents a vast expanse of time. Therefore, when we talk of such great lengths of time it can only be compared to other phenomena that occured over long periods of time. By this process we see that geologic time must be conceived of as being relative. We can compare 250 million years with 500 million years, 100,000 years with 50,000 years in the ratio of small whole numbers such as twice as long, one-half as long. These lengths of time have been determined to a fairly accurate degree by the events which have occured such as the development of mountains, the evidence of first life on earth, and the glacial periods; all have been dated and placed in their proper sequence in the history of the earth. The student should become aware of the immensity of geologic time and the fundamental principles that guide the geologist in measuring those vast units of time that make up the different phases of the earth's history. He should be aware of the many events that have occured on the earth, as well as the many changes in the forms of life that have lived on the earth.

Introductory Activity:

Principle:

Rock layers can be identified by their position in a sequence of layers and by their index fossils. This activity will aid the pupil in identifying the rock layers in local outcrop and in determining their proper position in the geologic column. Most schools have within walking distance an outcrop of a rock formation. In this activity, the field is the laboratory and specimens of each layer of the outcrop can be brought to the classroom for study. The purposes of these activities is to demonstrate the concept of original horizontality, the law of superposition, and the use of index fossils to identify a particular rock formation and place the outcrop in the proper position in the geologic timetable.

Equipment:

The following equipment will be needed: Sketch pad, geologist's hammer (small pick or chisel), measuring tape, hand lens, geologic map of Missouri, a copy of Stratigraphic Section of Missouri, obtained from Missouri State Geological Survey in which the member of each formation is identified, a good reference on the geological history of North America, and the quadrangle map for the area being studied for obtaining elevations, locations, etc.

Procedure:

In order to lay the proper foundation for this phase of the investigation of our earth, the following procedures should be followed: Have students consult a historical geology text, geological survey reports, or scientific periodicals to make either a written or oral report of the geological history of their own area. Each pupil may report on a single geologic period. Discuss the meaning of key terms such as: original horizontality, superposition, bedding plane, stratigraphy, index fossil, stratigraphic correlation, unconformity, cross-bedding, geologic column, and other terminology used in this unit of study. If there are several outcrops at different elevations in the vicinity, so much the better. Have the students, as individuals or in teams, measure the different layers and sketch them to scale. Break off fresh specimens of rock of each layer and bring back to the laboratory for fossil identification. After using reference books, maps, and charts, have the students submit chronological reports of their findings, procedures, and conclusions based on their own observations. The strata should be located in the geologic column as completely as possible from era to formation to member. The teacher should, at all times, parry questions with questions as a means of stimulating thinking on the part of the students.

Possible Outcomes:

Some possible outcomes are as follows: The student will become aware of the vastness of geologic time. By actual experience with dating and identifying a rock formation, he will regard other rock formations with a more critical and inquiring mind. He will gain insight into the field work of geologists. He will become aware of the geologic history in his particular area. He will learn to collect and organize the necessary data to solve a problem. He may, or may not, wish to make this his life's work. He has observed first-hand, some of the aggradational processes that are going on constantly. He now knows the real meaning of superposition, bedding plane, horizontality, sedimentation, intrusion, faunal, and floral succession and index fossils.

Continuing Activities:

1. If possible, classes may visit the nearest museum or college geology department where they can study an exhibit of fossils of different types and different geological ages.
2. Have several students refer to a textbook on historical geology for more information on types of unconformities and make models to represent these types. Models can be constructed from styrofoam, plastic, clay, and cardboard.
3. Fossil impressions, molds, casts of leaves, shells, etc., may be made using plasticene or modeling clay and plaster of paris.
4. Some students may make a diorama to represent the life of a particular prehistoric period.
5. Students may take a field trip to a nearby area of sedimentary rock of marine origin. Ask them what evidence they find there that these rocks were formed under water. A collection of fossils can be developed.
6. An exhibit may be arranged to show how fossils are formed.
7. The students may develop reports on such topics as the history of dinosaurs, flying reptiles, and fossil man.
8. Have a student prepare a report, on the significance of the coal deposits found in the Arctic and Antarctic regions.
9. Students may be asked to report on one of the following topics:
   Points of Geologic Interest in the State of Missouri, History of the Grand Canyon, History of the Great Lakes.

10. On a map of North America, show the distribution of land and water during one or more geological periods.

11. With the use of a magnifying lens, note the many flashes that are emitted from the hands of a radium-dial clock. What relation has this phenomenon to radioactivity?

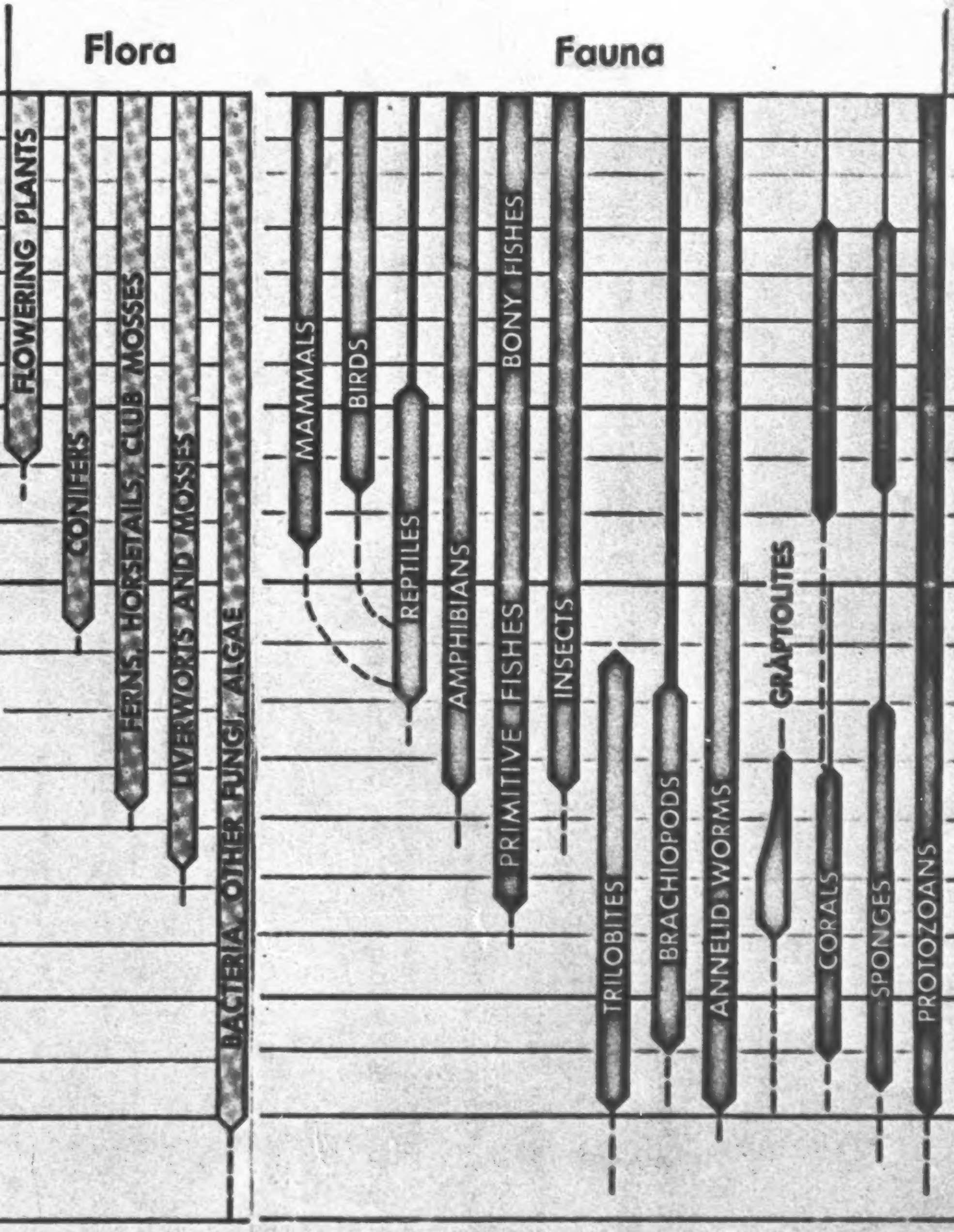
Fundamental Concepts:

- The earth has been developing for billions of years.
- The earth is thought to be more than 4.5 billion years old.
- Several theories as to how the earth was formed are: **Nebular Hypothesis, Planetesimal Hypothesis,** and **Tidal Hypothesis.**
- To systematize the information from this continuous record, man has established a time scale using arbitrary divisions based on the **evolvement of life** and the predominance of mountain-building activity over **erosion** and **sedimentation.**
- The **geologic time scale** or **geologic column** is a reference system into which geologic events can be fitted in proper chronological sequence.
- The units of geologic time are: **eras, periods, epochs,** and **ages.**
- Major divisions of geologic time are known as **eras.** The subdivisions are based on the highest type of life that existed during that interval. **Guide** or **index fossils** are keys to **stratigraphic succession** and correlation. They form the basis for the study of **paleontology.**
- Most formations of sedimentary rocks contain distinctive types of **fossils** by which they can be identified.
- Geologic events of the past can be interpreted and the relative time of their occurrence determined by a careful study of the rocks and their enclosed **fossils.**
- The surface of the earth and its plant and animal life is undergoing continual change.
- The processes that formed the land we now see, have been working intermittently and at varying, but usually slow, rates throughout **geologic time.**
- Although the geologic record is incomplete in any one place, mountain building, gradation, and the evolvement of life appear to proceed in orderly sequence throughout geologic time.

GEOLOGIC TIMETABLE

EARTH AND TIME

Era	Period	Epoch	Duration in millions of years	Millions of years ago
CENOZOIC (Age of Mammals)	QUATERNARY OR NEOGENE	HOLOCENE (RECENT)	70	70
		PLEISTOCENE		
	TERTIARY OR PALEOGENE	PLIOCENE		
		MIOCENE		
		OLIGOCENE		
		EOCENE		
		PALEOCENE		
MESOZOIC (Age of Reptiles)	CRETACEOUS		65	135
	JURASSIC		45	180
	TRIASSIC		45	225
PALEOZOIC (Age of Invertebrates, Fishes, and Amphibians)	PERMIAN		45	270
	PENNSYLVANIAN	CARBONIFEROUS	60	330
	MISSISSIPPIAN		20	350
	DEVONIAN		50	400
	SILURIAN		40	440
	ORDOVICIAN		60	500
	CAMBRIAN		100	600
PROTEROZOIC	KEWEENAWAN		1,100	1,700
	HURONIAN			
ARCHEOZOIC	[Primeval Oceanic]		900	2,600
	[Waterless]		1,900	4,500 +
COSMIC	[Earth's Origin]		?	?



Variation in width of bar indicates relative abundance of a group.

After Miller and Haub General Zoology Holt, Rinehart and Winston, Inc.

THE GEOLOGIC TIME SCALE

The Geologic Time Scale covers that interval of time from the formation of the first rocks in the earth's crust to the present. The length of this interval of time has been determined from a study of the rocks exposed at the surface of the earth and those recovered from well borings. It covers an interval of many millions of years. Throughout this time, rocks have been formed by the various geologic processes in the same manner as they are today. At present, a great deal of rock-forming material is being deposited at the mouth of large rivers as accumulations of sand and clay. As in past geologic ages, this material will eventually form the sandstone and shale beds so familiar to many of us.

Since the rock-forming processes have been continuous, rock formations are of various ages. In Missouri, the oldest rocks are the granite and related rocks of Precambrian age and are exposed at the surface in the St. Francois Mountains of southeastern Missouri. Radiometric age determinations indicate that they were formed one and a quarter to one and a half billion years ago. All other rock units in the state were deposited after the Precambrian rocks, but long before the deposits of clay, sand, and gravel in our modern streams and rivers.

In order to date the time during which various rocks were formed, geologists have divided the long expanse of time covered by the geologic time scale into time units called eras and periods. Thus, as the historian divides time into years, months, and days, the geologist divides geologic time into eras, periods, and smaller divisions.

The major divisions of the geologic time scale and the type, distribution, and economic utilization of rocks in Missouri are listed on the following pages. For example, the Mesozoic era is estimated to have lasted 167 million years. It has been subdivided into the Triassic, Jurassic, and Cretaceous periods. Geologists have determined that these periods lasted 49, 46, and 72 million years, respectively. Although rocks of Triassic and Jurassic age have not been found in the state, rocks of Cretaceous age do occur in the lowland region of southeastern Missouri. They are principally clays, sands, and limestones which were deposited in a shallow sea over 60 million years ago. The major economic products derived from them are water, ceramic clay, and sand.

γ

EARTH AND TIME

GEOLOGIC TIME SCALE, TYPES, AND USES OF MISSOURI ROCKS

MAJOR DIVISIONS		TYPE AND DISTRIBUTION OF ROCK	ECONOMIC UTILIZATION
ERAS	PERIODS		
CENOZOIC	**QUATERNARY** 0 1,000,000 Q	*Glacial deposits; loess; silt, sand, and gravel in modern streams and rivers.*	*Parent material of much of state's soil; important source of water; chief source of sand and gravel.*
	TERTIARY 1 63,000,000 T	*Sand, gravel, clay, and shale; largely restricted to Lowland region of southeastern Missouri.*	*Water, ceramic clay, bleaching clay.*
MESOZOIC	**CRETACEOUS** 64 72,000,000 K	*Clay and sand; restricted to southeastern Missouri as above.*	*Water, ceramic clay, sand.*
	JURASSIC 136 46,000,000 J	*No rocks of Jurassic age in state.*	
	TRIASSIC 182 49,000,000 TR	*No rocks of Triassic age in state.*	
PALEOZOIC	**PERMIAN** 231 50,000,000 P	*Sandstone; known from single locality in Atchison County.*	*No economic utilization.*
	PENNSYLVANIAN 281 30,000,000 IP	*Shale, limestone, sandstone, clay, and coal; present in more than two-thirds of the counties of the state; extensive in western and northern Missouri.*	*Coal, ceramic materials (including fireclay); limestone and shale for cement manufacture; oil, gas, and water; an important source of limestone in many western and northern counties; asphaltic sandstone, and iron.*
	MISSISSIPPIAN 311 35,000,000 M	*Predominantly limestone, some shale; principal areas of outcrop are southwestern, central, east-central, and northeastern parts of the state.*	*Lime, limestone, marble (Carthage), raw material for cement, water, tripoli, lead, zinc, and iron.*
	DEVONIAN 346 60,000,000 D	*Predominantly limestone; exposed in central, eastern, and southeastern Missouri.*	*Limestone, marble (Ste. Genevieve Co.).*
	SILURIAN 406 20,000,000 S	*Predominantly limestone; exposed in northeastern and southeastern Missouri.*	*Limestone and dolomite.*
	ORDOVICIAN 426 75,000,000 O	*Dolomite (magnesian limestone), limestone, sandstone, and shale; extensively exposed in Ozark area as far north as Montgomery County and west to McDonald and St. Clair counties; also exposed in parts of Ralls, Pike, and Lincoln counties.*	*Sand for glass and ground silica, limestone, dolomite, water, oil (St. Louis County), building stone, raw material for cement, iron, and terrazzo chips.*
	CAMBRIAN 501 100,000,000 Є	*Dolomite, sandstone, and shale; major outcrops restricted to St. Francois Mountain area.*	*Lead, zinc, silver, cobalt, nickel, copper, barite, iron, water, dolomite, terrazzo chips, and building stone.*
PRECAMBRIAN 601 *Includes several divisions of Era rank. Total time involved may have been as much as four billion years.*		*Igneous and metamorphic rocks; igneous exposed in St. Francois Mountain area.*	*Iron, granite for building and monumental stone.*

NOTE: Age data based on latest published results of isotopic measurements.
Chart not drawn to scale; 0-601 : cumulative age in millions of years.

MARCH 1964

MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES
BOX 250, ROLLA, MISSOURI 65401

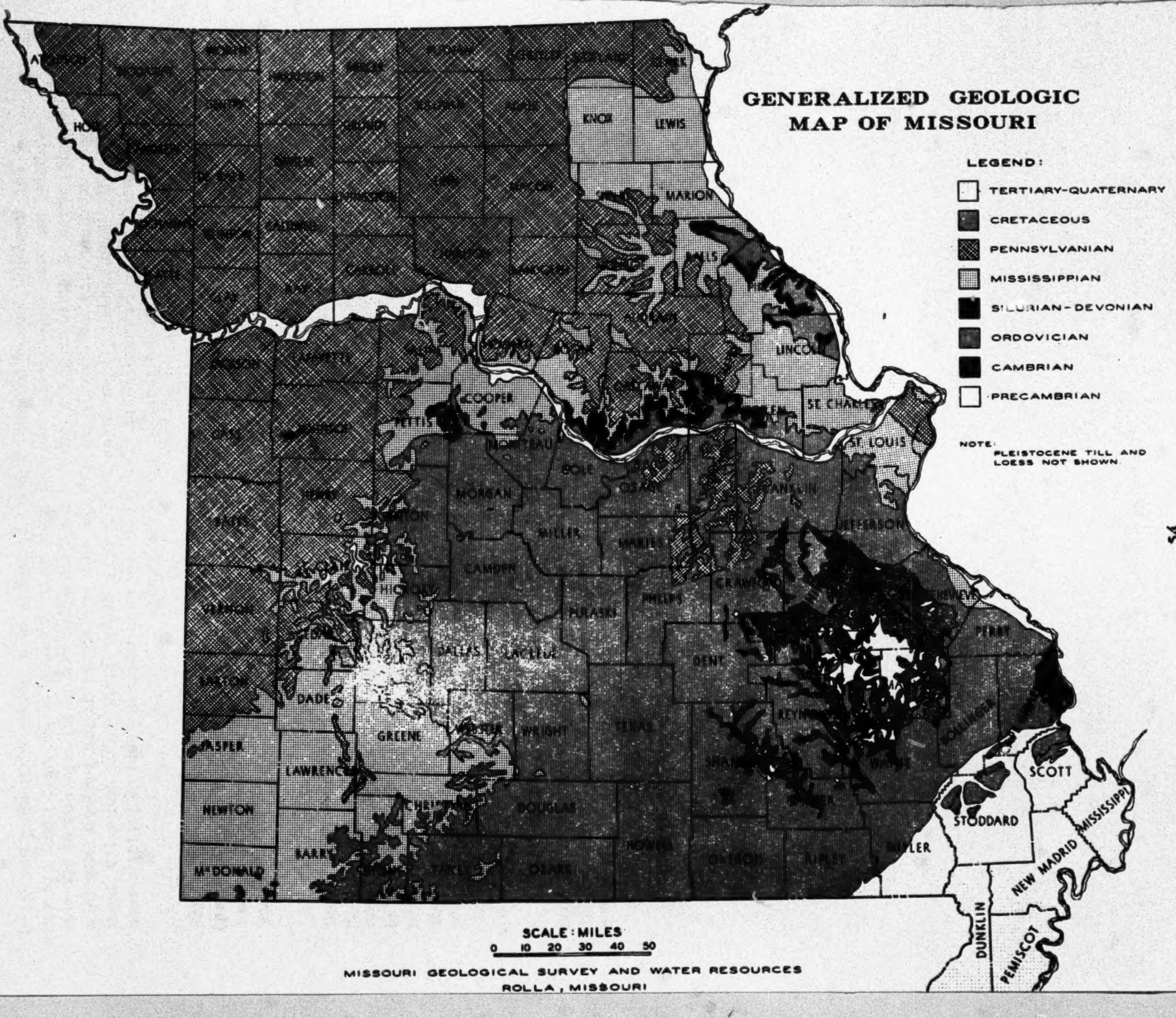
THE GEOLOGIC MAP OF MISSOURI

The Geologic Map of Missouri shows, by means of a system of shading and lined symbols, the area underlain by rocks of each major division of geologic time. For example, areas in Missouri where rocks of the Ordovician Period are exposed at the surface, or where they lie directly beneath the soil, are shown on the geologic map by a vertically lined symbol. These areas include most of the Ozark region and a few small areas north of the Missouri River. The symbol for each major division of geologic time is listed to the right of the geologic map in the legend.

The legend to the geologic map also indicates the time order in which rocks of the major geologic divisions were deposited. The symbol for the oldest rocks (Precambrian) is shown in white at the bottom of the legend, while the symbols for rocks deposited during the successively younger periods and eras are listed above that of the Precambrian.

In a complete rock section, the legend would represent the sequence of rocks encountered in a well which was started in the Quaternary deposits and was drilled through all successively older strata until it bottomed in the Precambrian. However, in most places the rock record is incomplete. Some periods are not represented by layers of rock because rocks of these periods were never deposited or because they were removed by erosion after they were deposited. This is the case in most of the Ozark region where the entire sequence of rocks overlying the Ordovician is absent. In other parts of the state, a more complete section is present. For example, in northwestern Missouri rocks of Quaternary, Pennsylvanian, Mississippian, Devonian, Silurian, Ordovician, Cambrian, and Precambrian age have been encountered in deep wells.

In general, the rock structure of Missouri may be said to resemble an overturned saucer; the oldest rock, or Precambrian, is exposed in a small area in the center of the saucer, encircled by successively younger rock layers which dip off and away from the center.



GENERALIZED GEOLOGIC MAP OF MISSOURI

LEGEND:
☐ TERTIARY-QUATERNARY
■ CRETACEOUS
▨ PENNSYLVANIAN
▨ MISSISSIPPIAN
■ SILURIAN-DEVONIAN
■ ORDOVICIAN
■ CAMBRIAN
☐ PRECAMBRIAN
NOTE: PLEISTOCENE TILL AND LOESS NOT SHOWN.
KNOX
LEWIS
MARION
LINCOLN
ST. CHARLES
ST. LOUIS
COOPER
PETTIS
MORGAN
MILLER
CAMDEN
PULASKI
CRAWFORD
DENT
PERRY
JEFFERSON
DADE
GREENE
LAWRENCE
JASPER
NEWTON
McDONALD
BARRY
DALLAS
LACLEDE
WRIGHT
DOUGLAS
OZARK
HOWELL
STODDARD
SCOTT
MISSISSIPPI
NEW MADRID
DUNKLIN
PEMISCOT
SCALE: MILES
0 10 20 30 40 50

MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES
ROLLA, MISSOURI

Films:

"The Fossil Story"	19 min., c	Shell Oil Company
"In the Beginning"	28 min., c	Magnolia Petroleum Company
"Long Time Intervals"	24 min., b/w	Educational Service, Inc.
"Prehistoric Times"		
"The World Before Man"	11 min., b/w	Coronet Instructional Films
"The Grand Canyon in Northern Arizona"	17 min., c	Santa Fe System Lines

Filmstrips:

"Earth is Born"	Life Magazine Filmstrip Division.
"Life Long Ago" (The Earth Science Series)	Row, Peterson and Co.
"Prehistoric Animals", Set No. 7	McGraw-Hill.
"Prehistoric Life", 6 filmstrips,	Encyclopaedia Britannica Films.
"The World We Live In"	Life Magazine Filmstrip Division.

Exhibits:

Stratigraphic Fossiliferous Rock Collection	Ward's Natural Science Est., Inc.
Student Stratigraphic Collection	Ward's Natural Science Establishment, Inc.

Charts:

Geologic Time Scale, Types, and Uses of Missouri Rocks	Missouri Geological Survey and Water Resources.
Generalized Geologic Map of Missouri	Missouri Geological Survey and Water Resources
Geologic Timetable, after Miller and Haub, **General Zoology**	Holt Rinehart and Winston, Inc.
Geologic Timetable, The World We Live In	D. Van Nostrand Co. Inc. p.279

Maps:

North America, Relief-like	Denoyer-Geppert Company.
North America, Outline	
United States, Outline	
Missouri	Geologic Map of Missouri Geological Survey.

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UNIT VII – THE EARTH'S NEIGHBORS--FRONTIERS OF THE FUTURE

Rationale:

A study of the heavenly bodies that compose the universe should be meaningful to man. He must understand the relationships which exist and place the relatively small planet, earth, in its proper perspective among the parts of the universe. Man has long been interested in this fathomless universe of space, in which our own earth is but a size-like grain of sand. The teacher and the pupils alike stand humbled before the mysteries of space; each using their imagination coupled with the known, to delve further into the order of the universe through the study of this unit.

Introductory Activity:

Basic Principles:

Space is so vast, that the earth is proportionately in size like a tiny grain of sand. The distance to the heavenly bodies can be measured in **light years.** Our sun is the nearest star to earth. It is a star of average size, yellow in color, and furnishes earth with **radiant energy.**

How Do We Know?

The telescope, the spectroscope, and the recent manned and unmanned flights into space have revealed a great deal of knowledge about the solar system. Careful study, mathematical calculations, and observation have added more; however, most facts about the universe still remain undiscovered. This unit offers many opportunities for "how do we know" activities and class discussion.

Equipment:

The following films would be excellent introduction to astronomy.

"Understanding Our Universe"	11 min.	Coronet 1958
"Understanding Our Earth"	11 min.	Coronet 1958
"The Solar Family"	11 min.	EBF 1936
"The Solar System"	11 min.	Coronet 1951
"The Big Sun and our Earth"	11 min.	Coronet 1957
"The Moon and How it Affects Us"	11 min.	Coronet 1958
"The Milky Way"	15 min.	International Screen Organization 1953

Procedure:

The student can best understand the nature and size relationships of the universe by having the opportunity to take an "overall" view through careful study of astronomy films.

Possible Outcome:

Students, it is hoped, will develop a better understanding of the size of the earth in comparison to the rest of the universe. They will also have opportunity to note the position and important effects of the sun.

Continuing Activities:

1. Planetarium models may be used to further student understandings. One such device shows the sun, earth, moon, and mercury. Another type shows the solar system in comparative sizes and positions.

2. The instructor can use a celestial sphere to illustrate **zenith, celestial equator,** and the positions of the stars for any latitude and season.

3. A plastic model of the Milky Way Galaxy may be used to demonstrate this relationship to other galaxies.

4. An easily made device for measuring distance to the heavenly bodies is produced with rule, protractor, weights and thumbtacks.

5. To illustrate the phases of the moon, a small globe painted half black and half white may be used. Keep the lighted half of this "moon" toward the sun, walk in counter clockwise direction around a seated student who represents the earth. The phases are plainly seen and can be named in order.

6. To demonstrate that the moon and mercury rotate once as they revolve, seat a student who represents the earth (or sun), and walk around him slowly keeping your face toward him. Thus you turn once around (rotate) as you walk around once (revolve).

7. A model may be designed to illustrate the tides. Make this from three colored discs of plastic with one cut to represent the earth; another slightly large to represent the oceans; and the third cut in an oval shape to represent the bulges of the ocean at spring tides. These three pieces are fastened together at the center so they pivot freely. Points representing the daily positions of the moon placed along the edge of the earth circle enable one to show the daily movements of the tides.

Fundamental Concepts:

- All stars perhaps evolved from clouds of gas and **cosmic** dust drifting in space that massed, contracted, and rotated into their present shapes.

- Our **Solar System** lies near the rim of the great **Galaxy** of the **Milky Way,** which is but one small island-like universe among 100 billion others whirling together in space.

- Our Solar System consists of the sun at the center, nine major planets and their thirty-one **satellites,** several thousand **planetoids,** thousands of **comets,** and billions of **meteoroids** revolving around it.

- The sun has 700 times as much matter as all of the rest of the Solar System put together. About 99 percent of all matter in the universe consists of the lightest elements, **hydrogen,** and **helium.**

- The sun furnishes the earth with radiant energy (produced by nuclear fission) which is necessary for the survival of life as we know it. It is believed that the earth's orbit lies in the only possible position in the Solar System where conditions are suitable for water to exist either as a liquid, gas, or solid. (According to one theory on the origin of the Solar System, a new-born earth and moon, reddened by the heat of their fires, rolled through space for at least five billion years. Great chunks of meteoroid material struck the earth and disappeared into its molten interior, while on the smaller, cooler moon, the wounds of collision remained visible.

- Nearer to the sun than Earth, are the small planets, Mercury and Venus. Beyond Earth is Mars, and then follow the giant spheres of Jupiter, Saturn, Uranus, and Neptune. Pluto is last in the procession from the sun, and is believed to be one of the smallest planets.
- Earth is the only planet which appears to have characteristics favoring life as we know it.

Recommended Additional Films: (addresses of sources listed in appendix)

"Constellations"	11 min. color	Indiana U. Audio Visual Center, 1961
"Energy from the Sun"	11 min. B/W	Encyclopaedia Britannica, 1955
"How Many Stars"	11 min. B/W	Moody Institute, 1954
"Realm of the Galaxies"	20 min. color	Horizons of Science, 1960
"This is the Moon"	11 min. B/W	McGraw Hill 1949

Maps and Charts: "Map ofSpace" 1962 Kao, Channing Wren, Ottenheimer Publishers, Baltimore, Md.

"Star Chart for Northern Skies: Lee, Dr. Oliver Justin, Rand McNally & Co.

References:

Barnet, Lincoln, and Editors of Life Magazine, 1962 **The World We Live In**, Time, Incorporated, N. Y.

Davis, Burnett & Gross, 1961 **Science Discovery and Progress** Holt, Rinehart and Winston Inc. N. Y.

Earth Science Curriculum Project, 1966 **Investigating The Earth**, Earth Science Curriculum Project Publication American Geology Institute, Houghton Mifflin.

McCracken, Decker, Read and Yarian, 1964 **Basic Earth Science**, Singer Science Series, L.W. Singer Co., Chicago, Ill.

Namowitz, S.P. and Stone, D.B. 1966 **Earth Science The World We Live In**, D. Van Nostrand, Princeton, New Jersey.

NASA, **Aeronautics and Space Bibliography for Secondary Grades**, National Aero Space Education Council, for sale by the U.S. Govt. Printing Office, Washington, D.C. 20402 35¢

Pella and Wood, 1964 **Physical Science for Progress**, Prentice Hall, Englewood Cliffs, New Jersey.

Ramsey, Wm. L., and Burckley, Raymond A., 1961 **Modern Earth Science**, Holt, Rinehart and Winston Inc. N.Y.

Secondary School Science Project, Time, Space, and Matter Investigating The Physical World, Princeton U., Princeton, N. Jersey.

Wolfe, Battan, Fleming, Hawkins and Skornik, 1966 Earth and Space Science, D.C. Heath & Co., Boston, Mass.

APPENDIX

APPENDIX

Address of Suggested References

(Not intended as an approved list or considered all inclusive.)

Almanac Films, Inc.
516 Fifth Avenue
New York 36, New York

American Geological Institute
1444 North Street, N.W.
Washington, D. C. 20005

American Petroleum Institute
Education Department
1271 Avenue of the Americas
New York, New York 10020

American Telephone and Telegraph Co.
195 Broadway
New York, New York

Barnes and Noble, Inc.
105 Fifth Avenue
New York, New York

Bell Telephone System
(Call or write your local telephone business office)

Cenco Educational Films
1700 West Irving Park Road
Chicago, Illinois

College Entrance Book Company
101 Fifth Avenue
New York, New York

Coronet Instructional Films
Division of Esquire, Inc.
65 East South Water Street
Chicago, Illinois

Denoyer, Geppert Company
5235 Ravenswood Avenue
Chicago 40, Illinois

Doubleday and Co., Inc.
575 Madison Avenue
New York, New York

Earth Science Curriculum Project
P. O. Box 1559
Boulder, Colorado 90301

Eckert's Mineral Research
110 East Main Street
Florence, Colorado

Encyclopaedia Brittanica Films
1150 Wilmette Avenue
Wilmette, Illinois

Film Associates of California
11014 Santa Monica Blvd.
Los Angeles 25, California

Film Images, Inc.
1860 Broadway
New York, New York

Golden Press, Inc.
One West 39th Street
New York, New York

Grolier Educational Corporation
575 Lexington Avenue
New York, New York 10022

Jam Handy Filmstrips Company
2821 East Brand Blvd.
Detroit, Michigan 48211

Harper and Row
49 East 33rd Street
New York, New York

D. C. Heath and Company
285 Columbus Avenue
Boston 16, Massachusetts

John J. Hennessy Pictures
1702 Marengo Avenue
South Pasadena, California

Holt, Rinehart and Winston
383 Madison Avenue
New York, New York

Horizons of Science
Five East 57th Street
New York 22, New York

Houghton-Mifflin
Boston,
Massachusetts

Johnson Hunt Productions
LaCenada,
California

Indiana University
Audio Visual Center
Bloomington, Indiana 47405

International Film Bureau
332 South Michigan Avenue
Chicago, Illinois

Kansas Geological Survey
Lawrence,
Kansas

Life Magazine, Filmstrip Division
Rockefeller Center
New York 20, New York

McGraw-Hill Text Films
330 West 42nd Street
New York 36, New York

Missouri Division of Geological Survey
and Water Resources
P. O. Box 250
Rolla, Missouri

Modern Learning Aids
Division of Modern Talking Picture Service
Three East 54th Street
New York, New York (Offices in major cities)

Modern Talking Pictures
3718 Broadway
Kansas City, Missouri

Moody Institute of Science
12,000 East Washington Blvd.
Whittier, California 90606

Natural History Press
New York,
New York

Ohio State University
Columbus,
Ohio

Prentice-Hall
Englewood Cliffs,
New Jersey 07632

Rand McNally & Company
P. O. Box 7600
Chicago, Illinois 60680

Random House
457 Madison Avenue
New York 22, New York

Row Peterson and Company
Evanston,
Illinois

Santa Fe System Lines
Public Relations Department
Eighty East Jackson Boulevard
Chicago 4, Illinois

Science Associates
P. O. Box 216
Princeton, New Jersey

Science Clubs of America
Science Service
1719 North Street N.W.
Washington D. C. 20036

Film Library
Shell Oil Company
160-70 Northern Boulevard
Flushing 58, New York

Society for Visual Education, Inc.
1345 Diversey
Chicago, Illinois

Socony-Mobil Oil Co., Inc.
Film Library
150 East 42nd Street
New York 17, New York

Public Relations Department
Socony Mobil Oil Company
150 East 42nd Street
New York, New York

Simon and Schuster
One West 39th Street
New York, New York

Syndicated Films
1022 Forbes Avenue
Pittsburg 19, Pennsylvania

Time-Life, Inc.
Time-Life Building
Rockefeller Plaza
New York, New York

U. S. Bureau of Mines
Graphic Services
4800 Forbes Avenue
Pittsburgh, Pennsylvania

U. S. Bureau of Mines
U. S. Department of the Interior
4800 Forbes Avenue
Pittsburgh, Pennsylvania 15213

U. S. Geological Survey
U. S. Department of the Interior
Washington D. C. 20242

United World Films
221 Park Avenue, South
New York, New York 10003

University of Chicago Press
5750 Ellis Avenue
Chicago, Illinois

University of Texas Press
2211 Red River Street
Austin 12, Texas

Film Library
University of Wisconsin
Madison, Wisconsin

D. Van Nostrand
120 Alexander Street
Princeton, New Jersey

Viking Press
625 Madison Avenue
New York, New York

Walt Disney Productions
Hollywood,
California

Ward's Natural Science Establishment
P. O. Box 1712
Rochester, New York

John Wiley & Sons
440 Park Avenue
New York, New York